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BULLETIN
OF THE
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INTERNATIONAL RAILWAY CONGRESS ASSOCIATION.

INQUIRY INTO QUESTIONS OF IMMEDIATE INTEREST.

(Decision taken by the Permanent Commission at its Meeting held on July 29th, 1933.)

QUESTION I.

Rail motor cars from the point of view of their construction.

COMPLETE REPORT [1]

(Countries of the European Continent)

by L. DUMAS,
Ingénieur en chef adjoint du Matériel et de la Traction, French Nord Railway,
and JEAN LÉVY,
Chef adjoint du service du Matériel et de la Traction, French State Railways.

FOREWORD.

This report contains :

first of all, a description, part by part, of the apparently best designs;

then a summary of the original features of the principal railcars in existence, classified by the country of origin.

It was found quite impossible to describe all the railcars now in service; there is, in fact, a very great number of types, some of them already old, with features that have since been discontinued. This report is limited to those a very large number of which are in service at the present time, or those with original features likely to be retained in new constructions.

The report deals with *petrol* railcars as well as those with *diesel* engines; but as the petrol engine has been adapted to railcar use without modification, no detailed description of it will be given. It should be pointed out, however, that if the present tendency is to develop the diesel engine with its lower fuel consumption, its greater power per engine, and its reduced fire risk, certain design-

(1) This report is a complete and up-to-date study of the whole question of railcars as regards the European Continent, including revised data in connection with part A (Engines, etc.), and part B (Body, etc.), as well as a new chapter dealing with steam railcars. Consequently it supersedes the reports by the same authors as published in the October 1934 and June 1935 *Bulletins*.

ers or users remain faithful to the explosion motor as being lighter and absolutely reliable in service.

It seemed well to start this report on the design and construction of rail motor cars with a short chapter on the test methods and the measuring devices by which it is now possible to compare, from the practical point of view, the different types of railcars actually in service, and to measure the stresses these vehicles set up in the track, and between their different component parts.

By such tests and measurements alone will it be possible, on the one hand, to make a wise choice from among the different prototypes, and on the other, to improve the behaviour of vehicles on the track, and eventually to increase their speed.

If, as the Reporters earnestly hope, the application of these tests and measurements quickly became general, the field of possible comparisons would be considerably extended, and the development of the railcar would be greatly speeded up.

The plan of the present report is as follows :

Chapter I. — Test methods and measuring instruments.

Chapter II. — Diesel traction engines for railcars.

Chapter III. — Mechanical transmissions and distant control.

Chapter IV. — Electric transmissions.

Chapter V. — Hydraulic transmissions.

Chapter VI. — Running gear. — Bogies.

Chapter VII. — Brake gear.

Chapter VIII. — Auxiliary apparatus.

Chapter IX. — Steam railcars.

Chapter X. — Underframe and body.

Chapter XI. — Arrangements.

Chapter XII. — Heating and ventilation.

Chapter XIII. — Fire protection.

Chapter XIV. — Railcars in the various countries.

* * *

CHAPTER I.

TEST METHODS AND MEASURING INSTRUMENTS.

I. — *Railcar constants and their determination.*

These constants are ascertained in France by the method developed by Messrs. Ferrand and Rousselet, of the State Railways. By using this method, the following characteristics can be ascertained for each type of railcar :

1. the running resistance constant F_0,
2. the aerodynamical resistance constant KS.

These two constants are those used in the speed resistance curves :

$$F = F_0 + KSV^2;$$

3. the efficiency of the transmission;
4. the efficiency of the gear box at a particular gear ratio;
5. the gradient climbing capability;
6. a new constant called « nervosité relative » or « relative accelerative aptitude ».

1. *Running resistance constant* F_0.

This constant is found by allowing the coach to run at low speed, with the engine cut out, up a known gradient of, for example, 5 mm. per metre (1 in 200), and noting the times taken to cover each 100 metres to rest. The deceleration is then calculated, and from it F_0.

2. *Aerodynamic constant KS.*

This constant is obtained from the maximum coasting speed of the vehicle as follows. The vehicle is allowed to run down different gradients with the engine cut out, the gradients being about 1 in 40 for vehicles on pneumatic tyres, and 1 in 100 for steel-tyred coaches. The limiting speed is obtained by successive approximations from the speeds recorded.

When these two constants, F_0 and KS,

are known, the following curves can be accurately drawn :

a) The decelerating force, or resistance-speed curve, in terms of the speed, on the level and on the various rising and falling gradients;

b) The resistance-speed curve, this being obtained from curve (*a*) by multiplying the ordinates by the speed.

3. *Efficiency of the transmission.*

When the maximum speed of the vehicle on the level has been found, the power required at the tread to maintain this speed is read off the curve. The ratio of this power to that developed by the engine at the speed considered gives the efficiency of the drive.

When the railcar is fitted with reversing gear with spur gears, the efficiency of the transmission can vary considerably according to the direction of running. A double series of trials should be carried out in such cases.

4. *Efficiency of the gear box.*

The efficiency taken is that of the last but one speed, that is to say it is the ratio of the powers at the tread in the last but one speed and in the last speed, the speed of the engine being constant. This efficiency is found in the same way as that of the transmission, but by measuring the maximum speed obtained in the last but one gear on a sufficiently steep rising gradient (about 1 in 50 in practice).

In the case of gear boxes with a multiplying gear, the efficiency of the direct drive is measured and those of the indirect drives above and below it.

If these two last efficiencies are to have any meaning, the engine must be in as good order as on the test bench.

5. *Gradient climbing capability.*

The climbing ability curve represents the speeds that can be reached on the different rising gradients. For each gradient, the curve giving the power at the tread on direct drive and intermediate gears can be drawn, as the curve of the engine power in terms of the speed of the railcar and also the efficiency of the drive and gear box are known.

For each gradient, the resistance in terms of the speed is also known. The intersection of these two curves gives the maximum speed on the gradient considered.

The curve of gradient climbing capability represents, within the limits of the scale, the theoretical acceleration the vehicle is capable of on the level, at the speed V, with the engine developing its maximum power at that speed.

6. *Acceleration aptitude constant.*

If the engine were to reaccelerate the vehicle under ideal conditions, the starting curve would effectively coincide with the theoretical acceleration curve, that is to say the curve representing its gradient climbing capability, and everything would go on as if the engine were working under a constant regime when the curve was drawn. In practice, however, some time is lost by the engine in starting up and in running up to maximum power.

The accelerative capability of the railcar can be represented by the ratio between the ordinates of the curve of actual starts and those of the theoretical curve (corresponding to the curve of gradient climbing capability). The starting curves are, of course, the usual speed-time curves.

It is indispensable that the whole of the above trials be carried out on carefully selected gradients, accurately checked by the permanent way department. Care must be taken to avoid conditions likely to upset the results, such as wind, greasy rails, newly laid track, or track under repair, etc... One has to be sure too that the engine is developing its full power as on the test bench when its power curves were taken, and nothing more.

Some railway administrations use this

method for finding the different constants mentioned above for their new railcars. The results obtained are given in the table below.

Type of railcar.	Average axle load.	Running resistance.	Air resistance (value given in m./sec.) (in ft./sec.)	Efficiency of gear box.	Efficiency of transmission.	Efficiency on the top but one gear.	Liveliness or acceleration capability factor.
FRANCE.							
Michelines, 36 places. (6 pairs of wheels) (Main-line companies).	1 730 kgr. *(3 813 lb.)*	8.2 kgr. *(18.1 lb.)*	0.39 *(1.28)*	0.84	0.915	0.77	0.90
Michelines 56 places, (8 pairs of wheels) (fig. 117).	1 620 kgr. *(3 571 lb.)*	8.3 kgr. *(18.3 lb.)*	0.39 *(1.28)*	0.90	0.92	0.83	0.92
Aciéries du Nord (4 pairs of wheels), Winterthur drive.	11 000 kgr. *(24 250 lb.)*	1.85 kgr. *(4.08 lb.)*	0.36 *(1.18)*	0.94	0.90	0.84	0.95
Franco-Belge triple unit, electric drive (fig. 122).	Power: 12 500 kgr. *(27 557 lb.)* Trailer: 8 300 kgr. *(18 300 lb.)*	2.60 kgr. *(5.73 lb.)*	0.42 *(1.38)*	»	Notch V 0.84	»	0.60 starting and 1 after 70 km. (43.5 miles) an hour.
HUNGARY.							
Ganz (4 pairs of wheels) 2 engines.	14 500 kgr. *(31 970 lb.)*	3.0 kgr. *(6.60 lb.)*	0.52 *(1.71)*	0.96	0.89	0.87	...
Ganz (4 pairs of wheels) 2 engines, with 2 trailers (fig. 129).	Power: 14 500 kgr. *(31 970 lb.)* Trailer: 10 500 kgr. *(23 150 lb.)*	2.11 kgr. *(4.65 lb.)*	0.78 *(2.56)*	0.96	0.89	0.87	...
Ganz (4 pairs of wheels) one engine (fig. 130).	9 750 kgr. *(21 500 lb.)*	1.74 kgr. *(3.84 lb.)*	0.39 *(1.28)*	0.96	0.89	0.87	...

The Belgian National Railways Company made similar tests with an eight-wheeled 175-h.p. Maybach railcar, but used a 3-term equation of the form $A + BV + CV^2$ and obtained the values :

$A = 2.850$
$B = 0.046$
$C = 0.0002.$

The German Reichsbahn has also made systematic tests, which only differ from those of the French railways in a few details.

Reducing the air resistance constant.

Many wind flume tests with models have been made in various laboratories : Friedrichshafen - Göttingen Technische Hochschule, Berlin; Issy-les-Moulineaux; Saint-Cyr. The results of these tests agree and show that the minimum air resistance is to be obtained by :

1. streamlining the vehicle and its undergear;

2. making windows, doors, steps, etc., flush with the body;

3. fully closing in the space between the body units.

II. — *The starting curve of a railcar and its accurate determination.*

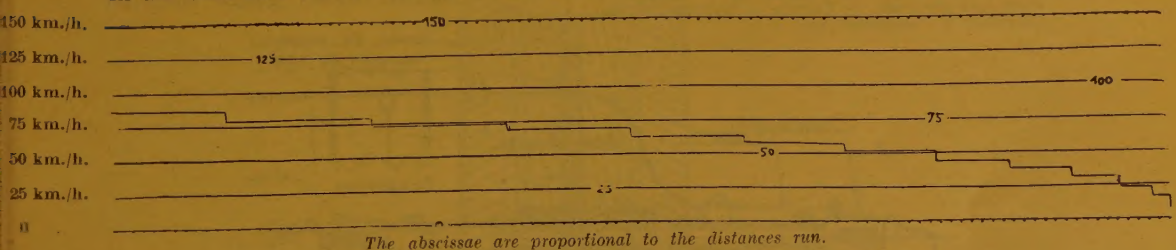
An accurate starting curve, giving the speeds at second intervals, can be obtained with an appropriate instrument, such as that made by the T. E. L. Company.

This instrument actually records, second by second, the average speed on a paper roll which moves 2 millimetres per metre travelled. The speed-time curve therefore is easy to draw. These curves are very instructive, as they show quite clearly that at each gear change in the case of a railcar with mechanical drive, the speed drops slightly; the better the design of the gear, the less the drop.

The drive is transmitted from the wheels to the instrument by a flexible cable with a standard connection.

The paper can be started or stopped at any time by means of a small lever in front of the instrument.

The difference between the speed over two successive intervals gives the speed increase (dv). If this change is directly measured and multiplied by a constant for the particular instrument, the absolue value of the acceleration is obtained. Accelerations of the order of 0.05 m. (2 inches) per second per second are readily measured.



The abscissae are proportional to the distances run.

Fig. 1. — Stopping curve of railcar, recorded by the T.E.L. apparatus.

The same instrument allows of the stopping curves of railcars being taken quite accurately; figure 1 shows such a curve (scale about 1/2).

The Reichsbahn obtains the same result by using an instrument which records accurately and simultaneously on a paper roll :

1. the distance travelled, by the number of revolutions of the wheels,
2. the time in seconds,
3. various marks made on the roll by hand.

III. — *Practical determination of the reactions felt at any point in the body of railcars.*

These reactions are important, affecting as they do the passengers' comfort. They can be measured with great accuracy by accelerometers, such as the H.M.P. (Huguenard, Magnan, Plagnol). This instrument can be set to operate longitudinally, transversely, or vertically, which gives the three components of the reactions.

The acceleration is measured by recording on a paper band, travelling proportionately to the time, the pressure exerted on a mixture of water and glycerine by a mass of mercury free to move in a direction parallel to that of the accelerations being measured.

This instrument is shown in diagram form in figure 2. It consists of a cylindrical tube in which the mercury is held between the two membranes a and b. One of them, b, forms the face of a box filled with compressed air by which the

instrument is calibrated. The other, *a*, transmits the pressure to a gauge having the lowest possible period of oscillation, through a mixture of water and glycerine. A needle valve is fitted in the glycerine-water pipe to control the movement of the gauge needle. The neutral or zero line of the scale can be set as desired by suitably regulating the air pressure in the air box. Both the gauge branch pipes are connected to a recording pen.

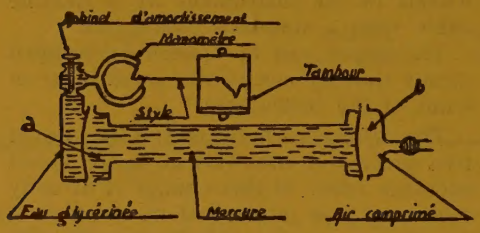


Fig. 2. — H.M.P. accelerometer.
Weight: 15 kgr. (33 lb.).

Explanation of French terms:

Robinet d'amortissement = Damping out valve. — Manomètre = Gauge. — Tambour = Drum. — Stylo = Recording pen. — Eau glycérinée = Mixture of water and glycerine. — Mercure = Mercury. — Air comprimé = Compressed air.

IV. — *Practical determination of the forces acting between the wheels and rails.*

These forces can be measured by the two instruments described below. These instruments were designed and perfected by Mr. MAUZIN, of the Paris-Orleans Railway.

1. — Mauzin wheel gauge recorder (fig. 3).

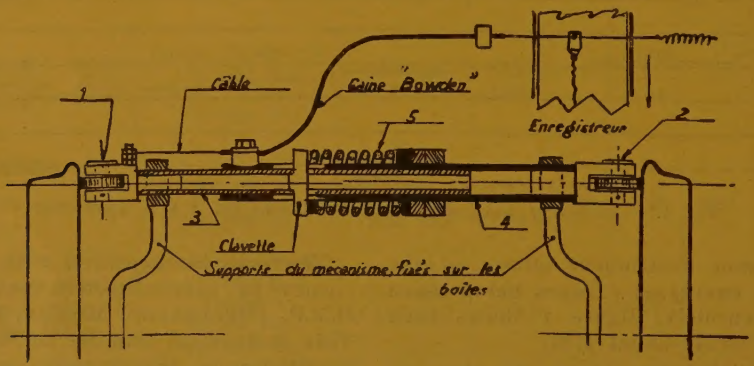


Fig. 3. — Diagram of the Mauzin apparatus recording the distance between wheels.

Explanation of French terms:

Câble = Cable. — Gaine Bowden = Bowden sheathing. — Enregistreur = Recorder. — Clavette = Pin. — Supports du mécanisme... = Bearers of the mechanism, fastened to the axle boxes.

This instrument consists essentially of two ball bearings (1 and 2) fastened to the ends of two telescopic tubes (3 and 4). A spring (5) keeps them away from each other and holds the ball bearings against the inside faces of the tyres of a pair of wheels at the top.

The differences of length given by the two tubes is transmitted by a Bowden cable to a recorder.

The instrument is calibrated by exerting a known force on the tyres, and shows the comparative magnitude of the dynamic forces to which the wheels are subjected.

2. Mauzin quartz piezo-electric instrument (fig. 4).

This instrument is based on the following principle :

When a plate of quartz is compressed,

electricity of contrary sign is produced on its two faces. The charge on the faces of the quartz is transformed into current by an electrometric lamp. The current from this lamp is amplified by resistance amplification (wireless type) and is then fed to an oscillograph, the amplitude of which gives the variations of the load on the quartz plate and, therefore, of the variations of the force acting.

This instrument is extremely accurate, as the inertia of the quartz may by overlooked.

The instrument is very easily calibrated, a hydraulic jack and pressure gauge being used for this purpose..

The pressure exerted on the quartz

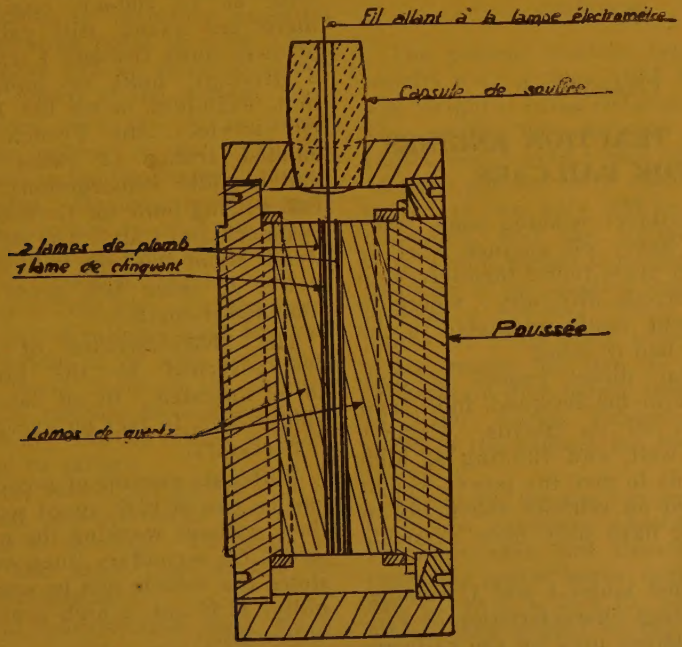


Fig. 4. — 2 quartz plates arranged in parallel.

Explanation of French terms:

Fil allant... = Wire to electrometer lamps. — Capsule de soufre = Sulphur bead. — 2 lames de plomb = 2 lead sheets. — 1 lame de clinquant = 1 foil sheet. — Poussée = Thrust. — Lames de quartz = Quartz plates.

should be perfectly along the normal thereto, and the wiring from the quartz to the first valve has to be extremely well insulated (beads of pure sulphur are used to insulate the wire, the whole being carried in a tube filled with dry air).

The Reichsbahn has perfected a similar method in which the reactions are measured by a pile of thin carbon washers; the variation of load of this pile produces a variation of the contact resistance, which is measured by a Wheatstone bridge connected to an oscillograph.

The Reichsbahn measures at the same time the variation in the deflection of the springs by means of an apparatus in

which deflection variation causes a variation in a resistance incorporated in a Wheatstone bridge.

* * *

CHAPTER II.

DIESEL TRACTION ENGINES FOR RAILCARS.

Railcar builders wishing some years ago to use heavy oil engines working on the diesel cycle found themselves up against a serious difficulty : where to find an engine really adaptable to the vehicle they had in mind.

The railcar diesel engine of over 100 H.P. had to be designed, built, and perfected in all its details. Engines picking up well, and running at high enough speeds to give the power-weight ratio required on vehicles essentially of light weight, have only been available recently.

The attached tables I and II summarise the leading characteristics of railcar diesel engines used on the railways who replied to the questionnaire sent out by the International Railway Congress Association.

In dealing with the different details of the diesel engines, we presume that the general characteristics of these engines are known, and we shall therefore only call attention to the most interesting points of design so as not to be too long-winded.

The essential qualities of a railcar engine, it should be remembered, are : power, endurance, lightness, and economy.

Power.

The size, comfort, and speed of railcars have constantly grown from their earliest days, to meet service requirements. The original four-wheeled vehicles weighed some ten tons and carried about forty passengers at 60 km. (37.3 miles) an hour. Many of these vehicles still exist in Central Europe with 80 to 100-H.P. engines. Today there are rakes, still called railcars, of three units (usually 1 trailer between 2 driving), built or under construction, examples being the Dutch trains (in service), the French Nord articulated trains (2 rakes in service, and 8 under construction), besides the rakes being built for Germany, Belgium, Denmark and Italy. The different rakes weigh about 100 tons with a total horsepower of some 800, given by two or four diesel engines.

The characteristics of the railcar are governed by the kind of line to be operated. In all cases, considerable power, in fact an excess of power, is necessary.

With this amount of power, the stock can be run at high speed over the main lines without working the engine to its limit. On secondary lines with frequent stops, the vehicle can be accelerated rapidly, as if not, a high overall speed is impossible.

Table I shows that there are a number of railcar engines of 400-H.P.

Messrs. Renault are now perfecting a 16-cylinder, V-type engine, developing 500 H.P. at 1 500 r.p.m.; Mercedes-Benz a 450-H..P, and M.A.N. one of 420-H.P. The Reichsbahn has started the trials of a 600-H.P. supercharged Maybach engine for its fast railcars.

Endurance.

The railcar must have a good endurance and be free from liability to fail in service. For this reason the engine

should be nursed by not being run at full power all the time.

The diesel engine is still a novelty on the railways and the driving and maintenance staff are still not fully experienced with it. With the few units in service, spare vehicles are not always available at the key points from which the lines worked by railcars radiate. An engine which will run long mileages without trouble is therefore essential from an operating point of view. The desired mileage can be fixed at 75 000 km. (46 600 miles) at the present time.

The present tendency is to avoid working the engine at its maximum power, by increasing the available power per ton hauled. On most modern railcars 10 H.P. per ton is available, some users requiring about 15 H.P. per ton so as not to overstress the engine and to ensure it has a long life. For example, the Bugatti petrol railcars have 800 H.P. for a tare weight of 32 tons (or about 25 H.P. per ton). Some of the engines used on these coaches have done more than 100 000 km. (62 000 miles) without any overhaul or failure.

The engines should not be difficult to repair so that they are out of service as short a time as possible. The parts of engines of the same type should be strictly interchangeable.

Mechanical transmission, now much used in some countries, means an engine with particular qualities.

Whereas the stationary type of engine runs at constant speed with little load variation and the traction engine with electric drive works under certain well defined conditions, the railcar engine, especially with mechanical drive, has, on the contrary, to be able to develop its full torque under all conditions, over a very wide range of speeds.

This involves good combustion and minimum vibration.

The vibrations occurring at critical speeds must not be overlooked. By altering certain parts (in particular the crank shafts) and by very careful balancing (balancing each coupling by counterweights) the builders have succeeded in getting the speeds at which such vibrations are set up to lie outside the working speed range of the vehicle.

The less important vibrations have been suppressed by using dampers.

Lightness.

The present traction type of engine weighs some 6 kgr. (13.2 lb.) per H.P. The weight is being reduced all the time. This engine falls between the aircraft engine which must weigh less than 1 kgr. (2.2 lb.) per H.P. to be usable, and is expected to run only 300 hours between overhauls, and the stationary engine with which weight is unimportant. The lightness of the traction engine does not prevent it running 75 000 km. (46 600 miles) or 1 000 hours between repairs. These results are due to metallurgical progress on high-tensile light alloys, and to better design, through which the speed of the engines has been increased so much.

The above tendency is general, except in a few countries (Austria, Hungary, Czechoslovakia and Denmark). These countries prefer heavy engines (9 to 12 kgr. = 19.8 to 26.4 lb. per H.P.) with which they expect to run 100 000 km. (62 100 miles) between repairs (guarantee given by GANZ and FRICHS).

Economy.

Besides possessing the above qualities the railcar engine should be economical in ordinary service; it should use little fuel oil and especially lubricating oil.

Besides, the importance of a small gas oil consumption per horse-power/hour should not be exaggerated. Actually, a saving of a few grammes of fuel per horse-power/hour, whilst important in the case of a power station engine runn-

TABLE I. — **Characteristics of the engine**

Number.	ENGINE.	Licensee if any.	Horse-power		R. p. m., nominal.	Weight of engine	
			nominal.	maximum.		Kgr.	Lb.
1	KRUPP, F. A. type	DELAUNAY-BELLEVILLE.	65	78	1000	770	1697
2	FIAT	Built in Italy.	70	75	1700	...	...
3	C. L. M., 85 L. C. 3, 2-stroke	Junker licence. Built in France.	80	88	1500	570	1257
4	RENAULT, 6 cylinders	Built in France.	85	93.5	1500	1100	2205
5	GANZ	Built in Hungary.	95	110	1650	770	1697
6	C. L. M. 85 L. C. 4, 2-stroke	Junker licence. Built in France.	100	119	1500	800	1764
7	GANZ	Built in Hungary.	110	130	1000	1920	4233
8	RENAULT, 6 cylinders	Built in France.	110	120	1500	1000	2205
9	SKODA (horizontal engine)	Built in Czechoslovakia.	120	130	1600	870	1918
10	M. A. N.	Built in Germany.	120	150	1400	1025	2260
11	LORRAINE	Built in France.	120	152	1500	818	1803
12	GANZ	Built in Hungary.	125	150	1000	2000	4410
13	BERLIET	Built in France.	125	150	1500	1130	2491
14	M. W. M.	Built in Germany.	125	150	1000	1800	3968
15	GANZ	Built in Hungary.	130	150	1350	1050	2315
16	A. E. C.	Licensee for Italy (BREDA).	130	140	2000	641	1413
17	MERCEDES-BENZ	Built in Germany. Licensee in France: C.O.D.R.A.	135	150	1700	1100	2205
18	SAURER B X D, 4-stroke	Switzerland. Built in France.	140	154	1500	1160	2557
19	M. A. N.	Built in Germany.	150	160	1500	1340	2954
20	MAYBACH	Built in Germany.	150	155	1300	900	1984
21	C. K. D. (horizontal engine)	Built in Czechoslovakia.	150	180	1100	1670	3682
22	SAURER B X D (new type)	Switzerland. Built in France. Built in Czechoslovakia.	150	180	1500	1160	2557
23	BRNO-KRALOVO-POLSKA	Licensee in Austria : SIMMERING.	160	175	1300	2000	4410
24	GANZ	Built in Hungary.	160	190	1300	1700	3747
25	M. W. M.	Built in Germany.	170	225	800	2690	5920
26	M. A. N.	Built in Germany. Builder in France : ACENOR.	170	180	900	2200	4850
27	MAYBACH	Built in Germany.	175	180	1400	1100	2425
28	DEUTSCHE WERKE, KIEL (horizontal engine)	Built in Germany.	180	200	...	...	...
29	M. A. N.	Do.	190	225	1000	2060	4541
30	M. A. N.	Do.	210	225	1400	1490	3285
31	MAYBACH	Do.	210	220	1400	1200	2645
32	RENAULT (V-type)	Built in France.	220	240	1500	1560	3439
33	FRICHS	Built in Denmark. Builder in France : CORPET.	220	240	1000	1720	3792
34	GANZ	Built in Hungary.	220	310	1200	1850	4078
35	FRICHS	Built in Denmark. Builder in France : CORPET.	250	275	1000	2100	4630
36	RENAULT (V-type)	Built in France.	265	300	1500	1900	4189
37	M. A. N.	Built in Germany.	280	307	1400	1900	4189
38	GRAZ	Built in Austria.	300	330	1000	4000	8818
39	M. W. M.	Built in Germany.	300	350	1100	...	...
40	GANZ	Built in Hungary.	300	365	1200	2800	6173
41	SAURER B Z D (V type)	Switzerland. Built in France.	300	350	1500	2000	4410
42	MERCEDES-BENZ (V-type)	Built in Germany.	300	330	1500	1800	3968
43	CESKOMORAVSKA-KOLBEN-DANEK	Built in Czechoslovakia.	350	380	900	4360	9612
44	GANZ	Built in Hungary.	400	450	1450	3000	6615
45	SKODA	Built in Czechoslovakia.	400	440	1000	4700	10361
46	MAYBACH (V-type)	Built in Germany.	410	450	1400	2030	4475
47	M. A. N. (V-type)	Do.	420	450	1400	3150	6944
48	MERCEDES-BENZ (V-type)	Do.	450	500	1400	...	...
49	C. K. D.	Built in Czechoslovakia.	450	500	800	...	...
50	RENAULT (V-type)	Built in France.	500	550	1500	...	...

M.A.N. = Maschinenfabrik-Augsburg-Nürnberg. — M.W.M. = Motorenwerke-Mannheim. — A.E.C. = Associated Equipment Company.

use on the various Railways.

Weight / power ratio		Number of cylinders.	Bore		Stroke		Mean piston speed $V = \frac{CmNl/m}{30}$		Mean pressure 4-stroke cycle $382\,\frac{P}{D^2nVm/s}$		Fuel oil consumption per H.P./hour				Lubricating oil consumption per H.P./hour	
											Full load		Half load			
Kgr. / H.P.	Lb. / H.P		Milli-metres.	Inches.	Milli-metres.	Inches.	m./sec.	ft/.sec.	kgr./cm²	lb./sq. inch	Grammes.	Lb.	Grammes.	Lb.	Grammes.	Ounces.
.8	26.0	4	135	5.31	200	7.87	6.65	21.81	5.1	72.53	195	0.430	...	...	4	0.141
..	...	6	108	4.25	152	5.98	8.6	28.22	4.7	66.84	...	...	...	...	...	...
5.5	14.3	3	85	3.35	240	9.45	6.0	19.68	5.85	83.20	205	0.452	270	0.617	5 - 6	0.176-0.212
.7	25.7	6	115	4.53	170	6.69	8.50	27.88	4.8	68.27	210	0.463	250	0.551	5	0.176
3.1	17.8	8	105	4.13	140	5.51	7.68	25.20	5.35	76.09	200	0.441	224	0.494	3	0.106
6.78	14.9	4	85	3.35	240	9.45	6.0	19.68	5.5	78.23	214	0.472	280	0.617	4	0.141
7.5	38.6	6	150	5.91	185	7.28	6.15	20.17	5.05	71.83	195	0.430	220	0.485	3	0.106
0.0	22.0	6	125	4.92	170	6.69	8.50	27.88	4.8	68.27	210	0.463	250	0.551	3	0.106
7.2	15.9	8	110	4.33	150	5.91	8.0	26.25	4.7	66.85	200	0.441	212	0.467	10	0.352
8.5	18.7	6	140	5.51	180	7.09	8.40	27.56	4.6	65.43	182	0.401	217	0.478	8	0.282
6.8	15.0	6	126	4.96	180	7.09	9.0	29.53	5.5	78.23	200	0.441	230	0.507	6	0.212
6.0	35.3	6	160	6.30	185	7.28	6.15	20.18	5.05	71.83	195	0.430	220	0.485	3	0.106
9.4	20.7	6	135	5.31	180	7.09	6.59	21.62	4.7	66.85	202	0.445	241	0.478	2	0.071
4.4	31.7	6	150	5.91	200	7.87	6.65	21.82	4.7	66.85	190	0.419	225	0.496	...	...
8.1	17.8	6	135	5.31	185	7.28	8.30	27.23	5.45	77.51	200	0.441	224	0.474	3	0.106
5.0	11 0	6	115	4.53	142	5.59	9.8	32.15	6.2	88.18	4 - 5	pints	...	...	...	...
7.4	16.3	6	125	4.92	170	6.69	9.70	31.82	5.70	81.07	195-220	0.430-0.485	260	0.573	5 - 8	0.176-0.282
8 3	18 3	6	130	5.12	180	7.09	9.0	29.53	5.9	83.91	210	0.463	218	0.481	4 - 8	0.141-0.282
8.9	19.6	6	150	5.91	180	7.09	9.0	29.53	4.75	67.56	200	0.441	...	...	5	0.176
6 0	13.2	6	140	5.51	175	6.89	7.6	24.94	6.4	91.03	180	0.397	200	0.441	5	0.176
1.0	24 3	8	150	5.91	180	7.09	6.6	21.65	4.8	68.27	188	0.414	205	0.452	5	0.176
7.7	17 0	6	130	5.12	180	7.09	9.0	29.53	6.3	89.60	170	0.375	...	...	4 - 8	0.141-0 282
2.5	27.5	8	140	5.51	180	7.09	7.8	25.59	5.0	71.11	190	0.419	230	0.507	5	0.176
0 6	23.4	8	135	5.31	185	7.28	7.8	25.59	5.4	76.80	...	...	...	...	...	...
3.7	34.6	6	175	6.89	240	9.45	6.40	21.00	5.5	78.22	190	0.419	230	0.507	...	...
3.0	28.7	6	175	6.89	220	8.67	6.6	21.65	5.35	76.09	200	0.441	196	0.402	5	0.176
6.3	13.9	6	140	5.51	180	7.09	8.4	27.56	6.75	96.00	213	0.469	249	0.549	5	0.176
...	...	8	125	4.92	...	...	...	...	...	...	...	...	...	...	...	...
0.8	23.8	6	175	6.89	220	8.67	7.30	23 95	5.40	76.80	185	0.408	...	...	5	0.176
7.1	15.6	6	175	6.89	180	7.09	8.0	26.25	5.5	78.22	185	0.408	...	...	5	0.176
6 2	13.7	6	150	5.91	200	7.87	9.30	30.51	6.30	89.60	190	0.419	200	0.441	5	0.176
7.1	15.6	12	130	5.12	170	6.69	8.5	27.89	4.9	69.69	205	0.452	245	0.540	5	0.176
7.8	17.2	6	175	6.89	260	10.24	8.6	28.22	5.35	76.09	175	0.386	185	0.408	4	0.141
8 4	18.5	6	170	6.69	220	8.67	8.8	28.87	5.5	78.23	185	0.408	208	0.459	3	0.106
8.4	18.5	6	185	7.28	260	10.24	8.6	28.22	5.4	76.80	185	0.408	210	0.463	4	0.141
7.2	15.9	12	140	5.51	170	6.69	8.4	27.56	5.1	72.53	183	0.403	214	0.472	5	0.176
6.9	15.2	8	175	6.89	180	7.09	8.3	27.23	5.3	75.38	183.5	0.404	214	0.472	5	0.176
3.0	28.7	6	210	8.27	250	9.84	8.3	27.23	5.2	73.96	180	0.397	...	...	5	0.176
...	...	6	200	7.87	250	9.84	9.1	29 86	5.2	73.96	...	...	...	..	..	...
9.3	20.5	8	170	6.69	220	8.67	8.8	28.87	5.5	78.23	...	...	...	...	...	...
6.6	14.6	12	130	5.12	180	7 09	9.0	29.53	6.3	89.60	...	...	...	...	...	...
6.0	13.2	12	138	5.43	170	6.69	8 4	27 56	5.65	80.36	200	0.441	220	0.485	8	0.282
2.5	27.5	6	220	8.67	280	11 02	8.4	27.56	5.47	77.80	175	0.386	200	0.441	5	0.176
7.2	15.9	8	170	6.69	220	8.67	10 0	32.81	6 6	93.87	...	...	...	...	...	...
1.7	25.8	6	230	9.06	280	11.02	9.3	30.51	5.2	73.96	175	0 386	200	0.441	5	0.176
4.7(1)	10.4(1)	12	150	5.91	200	7.87	9.3	30.51	6 30	89 60	180	0 397	190	0.419	4	0.141
7.5	16.5	12	175	6.89	180	7.09	8.4	27.56	5.20	73.96	185 ±10%	0.408 ±10%	...	...	5	0.176
...	..	12	165	6 50	195	7.68	9.1	29.86	5.7	81.07	...	...	...	...	...	...
...	...	8	...	...	...	...	...	...	...	...	...	...	...	...	..	...
...	...	16	156	6.14	180	7.09	9.0	29.53	5.7	81.07	...	..	...	...	...	...

(1) Weight of engine without clutch, flywheel nor starter.

TABLE II. — **Constructional particulars**

Number.	ENGINE.	Nominal horse-power.	Injection.			Bearings.		Nature of connecting rod big end bearings.	Piston.
			Pumps.	Injectors.	Method of injection.	Number.	Nature.		
1	KRUPP, F. A. type . .	65	Krupp.	Krupp.	Direct.	5	Bronze. — Antifriction lined. Hoyt metal.	Bronze. — Antifriction lined. H D.	Light alloy
2	FIAT	70	Bosch.	Bosch.	Do.	...	...	...	...
3	C. L. M. 85 L. C. 3. 2-stroke	80	C. L. M.	C. L. M.	Do.	4	Bronze. — Antifriction lined.		Cast iron
4	RENAULT 6 cylinders .	85	Bosch-Lav.	Bosch-Lav.	Do.	7	Steel. — Antifriction.		Light alloy
5	GANZ	95	Ganz.	Ganz.	Precombustion chamber.	9	Bronze. — Antifriction. Glyco or Hoyt 10 alloy.		Cast iron
6	C. L. M. 85 L. C. 4. 2-stroke	100	C. L. M.	C. L. M.	Direct.	5	Bronze. — Antifriction.		Do.
7	GANZ	110	Ganz.	Ganz.	Precombustion chamber.	4	Bronze. — Antifriction. Glyco or Hoyt 10 alloy.		Do.
8	RENAULT 6 cylinders .	110	Bosch-Lav.	Bosch-Lav.	Direct.	7	Steel. — Antifriction.		Do.
9	SKODA (horizontal engine)	120	Bosch.	Bosch.	Do.	5	Roller.	...	Do.
10	M. A. N.	120	Bosch.	Bosch.	Do.	7	Bronze. — Antifriction.		Do.
11	LORRAINE	120	Bosch.	Bosch.	Precombustion chamber.	7	Steel. — Antifriction.		Aluminium
12	GANZ	125	Ganz.	Ganz.	Do.	4	Bronze. — Antifriction. Glyco or Hoyt 10 alloy.		Cast iron
13	BERLIET	125	Bosch.	Bosch.	Air injection chamber in piston.	7	Bronze. — Antifriction.	Steel. — Antifriction.	Light alloy
14	M. W. M.	125	M. W. M.	M. W. M.	Direct.	7	Bronze. — Antifriction.		Do.
15	GANZ	130	Ganz.	Ganz.	Do.	7	Bronze. — Antifriction. Glyco or Hoyt 10 alloy.		Cast iron
16	A. E. C.	130	Bosch.	Bosch.	Precombustion chamber.	7	Brass. — Antifriction.	Steel. — Antifriction.	Light alloy
17	MERCEDES-BENZ . .	135	Bosch.	Bosch.	Direct.	7	Bronze. — Antifriction.		Do.
18	SAURER B X D. 4-stroke (old type)	140	Bosch-Lav.	Bosch-Lav.	Injection air receiver.	7	Roller.	Bronze. — Antifriction.	Do.
19	M. A. N.	150	Bosch.	Bosch.	Direct.	7	Bronze. — Antifriction.		Do.
20	MAYBACH	150	Deckel.	Deckel.	Do.	7	Roller.	...	Do.
21	C. K. D. (horizontal engine)	150	Bosch.	...	...	5	Bronze. — Antifriction.	...	Aluminium
22	SAURER B X D (new type)	150	Bosch.	Saurer.	Direct.	7	Roller.	Lead-bronze alloy.	Do.
23	BRNO-KRALOVO-POLSKA	160	Bosch.	Bosch.	Do.	5	Antifriction.		Light alloy
24	GANZ	160	Ganz.	Ganz.	Do.	9	...	Special bronze.	Cast iron

Note. — M. A. N. = Maschinenfabrik-Augsburg-Nürnberg. — N. W. N. = Motoren Werke-Mannheim. — A. E. C. = Associ

e engines in use on the various Railways.

Kind of metal.				Lubrication.	Starting.	Control.
Connecting rods.	Crankshaft.	Casing.	Cylinders.			
Duralumin (Navy).	Nick.-chr. steel.	Silumin (light alloy).	Cast iron L.	Pressure.	Electric.	Mechanical.
...	...	...	...	...	...	...
k.-chr. steel.	Nick.-chr. steel.	Aluminium.	Cast iron L.	Pressure.	Electric. 1 starter.	Mechanical.
Do.	Nick.-chr. steel.	Cast iron.	Do.	Do.	Electric.	Do.
Steel.	Special Monicro steel.	Light alloy.	Cast iron S.	Do.	Do.	Do.
k.-chr. steel.	Nick.-chr. steel.	Aluminium.	Cast iron L.	Do.	Electric. 1 starter.	Do.
Steel.	Special Monicro steel.	Cast iron.	Cast iron S.	Do.	Electric.	Do.
ck.-chr. steel.	Nick.-chr. steel.	Do.	Cast iron L.	Do.	Do.	Do.
Special steel.	Silicon steel.	Cast steel.	Cast iron.	Do.	Do.	Do.
ck.-chr. steel.	Nick.-chr. steel.	Light alloy.	Do.	Do.	Do.	Do.
Do.	High-strength steel.	Aluminium.	Special cast iron L.	Do.	Do.	Do.
Steel.	Special Monicro steel.	Cast iron.	Cast iron S.	Do.	Do.	Do.
ck.-chr. steel.	Nick.-chr. steel.	Aluminium.	Special cast iron L.	Do.	Do.	Do.
Special steel.	Special steel.	Light alloy or welded steel plates.	Cast iron L.	Do.	Electric or compressed air. Heating plug.	Compressed air.
Steel.	Special Monicro steel.	Light alloy.	Cast iron S.	Do.	Electric.	Mechanical.
Special steel.	Special steel.	Electron alloy.	Do.	Do.	Do.	Do.
Do.	Nick.-chr. steel.	Silumin or aluminium.	Grey iron L.	Do. Dry sump.	Electric. Heating plug.	Do.
ck.-chr. steel.	Do.	Cast iron.	Special very hard cast iron L.	Pressure.	Electric. 2 starters. Heating plug.	Do.
Special steel.	Special steel.	Do.	Cast iron L.	Do.	Electric.	Do.
Do.	Do.	Light alloy.	Cast iron S.	Do.	Electric or compressed air.	Do.
Special steel.	Nick.-chr. steel.	Steel plates.	Steel L.	Do.	Electric.	Do.
ick.-chr. steel.	Do.	Cast iron.	Cast iron L.	Do.	Do.	Do.
Poldi steel.	Poldi steel.	Cast iron and silumin.	...	Do.	Electric generator.	...
Special steel.	Special steel.	...	Cast iron S.	Do.	Electric or compressed air.	Mechanical.

uipment Company.

S = Cylinders machined from solid casting. — L = Cylinders with lining.

TABLE II. —

Number.	ENGINE.	Nominal horse-power	Injection.			Bearings.		Nature of connecting rod big end bearings.	Piston.
			Pumps.	Injectors.	Method of injection.	Number.	Nature.		
25	M. W. M.	170	M. W. M.	M. W. M.	Precombustion chamber.	7	Bronze. — Antifriction.		Light alloy.
26	M. A. N.	170	Bosch.	Bosch.	Direct.	7	Bronze. — Antifriction (white metal).		Aluminium.
27	MAYBACH	175	Maybach.	Maybach.	Do.	7	Roller.		Aluminium alloy.
28	DEUTSCHE WERKE KIEL (horizontal engine)	180	Bosch.	Bosch.	...	...	...		...
29	M. A. N.	190	Bosch.	Bosch.	Direct.	7	Bronze. — Antifriction.		Light alloy.
30	M. A. N.	210	M. A. N.	Bosch.	Do.	7	Do.		Do.
31	MAYBACH	210	Deckel.	Deckel.	Do.	7	Roller.		Do.
32	RENAULT (V-type) . .	220	Précision mécanique.	Précision mécanique.	Do.	7	Steel. — Antifriction. Now white metal.		Do.
33	FRICHS	220	Bosch.	Bosch.	Do.	...	Steel. — Antifriction.	Bronze. — Antifriction.	Aluminium.
34	GANZ	220	Ganz.	Ganz.	Precombustion chamber.	7	Bronze. — Antifriction. Glyco or Hoyt 10 alloy.		Cast iron.
35	FRICHS	250	Bosch.	Bosch.	Direct.	...	...		Aluminium.
36	RENAULT (V-type) . .	265	Précision mécanique.	Précision mécanique.	Do.	7	White metal.	Lead-bronze alloy.	Do.
37	M. A. N.	280	Bosch.	Bosch.	Do.	7	Bronze. — Antifriction.		Do.
38	GRAZ	300	Bosch.	Bosch.	Do.	...	Do.		Do.
39	M. W. M.	300	M. W. M.	M. W. M.	Precombustion chamber.	...	Do.		...
40	GANZ	300	Ganz.	Ganz.	Do.	7	Do.		Cast iron.
41	SAURER B Z D (V-type)	300	Bosch.	Saurer.	Direct.	7	Roller.	Lead-bronze alloy.	Aluminium.
42	MERCEDES-BENZ (V-type)	300	Bosch.	Bosch.	Precombustion chamber.	7	Bronze. — Antifriction.		Light alloy.
43	CESKOMORAVSKA-KOLBEN-DANEK . .	350	Bosch.	Bosch.	Direct.	7	Antifriction	Antifriction	Do.
44	GANZ	400	Ganz.	Ganz.	...	...	...		...
45	SKODA	400	Bosch.	Bosch.	Direct.	8	Bronze. — Antifriction.		Aluminium.
46	MAYBACH (V-type) . .	410	Deckel.	Deckel.	Do.	7	Roller.	Roller.	Do.
47	M. A. N. (V-type) . . .	420	M. A. N.	Bosch.	Do.	14	Bronze. — Antifriction.		Light alloy.
48	MERCEDES-BENZ (V-type)	450	...	...	. .	...	...		...
49	C. K. D.	450	Bosch.	Bosch.	...	...	...		...
50	RENAULT (V-type) . .	500	Précision mécanique.		Direct.	9	White metal.	Lead-bronze alloy.	Aluminium.

Note. — M. A. N. = Maschinenfabrik-Augsburg-Nürnberg. — N. W. M. = Motoren Werke-Mannheim. — A. E. C. = Associat

Continued.)

Kind of metal.				Lubrication.	Starting.	Control.
Connecting rods.	Crankshaft.	Casing.	Cylinders.			
...	Do.	...	...	...	Do.	...
Nickel steel.	Nick.-chr. steel.	Cast iron.	Cast iron L.	Pressure.	Electric. Decompressor.	Mechanical and compressed air.
ck.-chr. steel.	Nick.-chrom.-tungsten steel.	Aluminium alloy.	Cast iron S.	Pressure. Spray nozzle in front of each bearing.	Heating plug. Compressed air.	Mechanical.
...	...	...	...	...	. .	...
Special steel.	Special steel.	Cast iron.	Cast iron L.	Pressure.	Electric.	Mechanical.
Do.	Do.	Steel.	Steel L.	Do.	Compressed air.	Do.
Do.	Do.	Light alloy.	Cast iron S.	Pressure. Spray nozzle in front of each bearing.	...	Do.
ck.-chr. steel.	Chr.-Mo.-Nick. steel.	Aluminium.	Cast iron L.	Pressure.	Electric. 2 starters.	Do.
Special steel.	Special steel.	Cast iron.	Do.	Pressure.	Electric generator.	Mechanical.
Steel.	Special Monicro steel.	Light alloy.	Cast iron S.	Do.	...	Do.
Special steel.	Special steel.	Cast iron.	Cast iron L.	Do.	Electric.	Do.
Pressed steel.	Do.	Aluminium.	Do.	Do.	Do.	Do.
Special steel.	Do.	Cast iron.	Do.	Do.	Do.	Do.
Do.	Do.	Do.	Do.	Do.	Do.	Do.
...	...	...	Do.	...	Do.	Do.
Steel.	Special steel.	Light alloy.	Cast iron S.	Pressure.	Do.	Do.
ck.-chr. steel.	Nick.-chr. steel.	Cast iron.	Cast iron L.	Do.	Do.	Do.
Special steel.	Special steel.	Silumin.	Grey iron.	Pressure. Dry sump.	Electric. Heating plug. Decompressor.	Do.
ck.-chr. steel.	Nick.-chr. steel.	...	...	Pressure.	Electric generator.	...
...	...	...	...	...	...	...
ck.-chr. steel.	Special steel.	Steel plates.	Cast iron L.	Pressure.	Electric.	Hydraulic.
Do.	Nick.-chr. steel.	Light alloy.	Cast iron S.	Pressure. Spray nozzle in front of each bearing.	Electric generator. Electric or compressed air. Heating plug.	Do.
Do.	Do.	Steel.	Steel L.	Pressure.	Electric.	Do.
...	...	...	...	...	...	...
...	...	...	...	...	...	...
Special steel.	Special steel.	Aluminium.	Cast iron L.	Pressure.	Electric.	Mechanical.

uipment Company. S = Cylinders machined from solid casting. — L = Cylinders with lining.

ing throughout the 24 hours is much less important in the case of a traction engine working intermittently.

Contrariwise, the consumption of lubricating oil, which increases rapidly with wear, especially with badly designed engines, and varies between 1 and 10, depending on the design of the engines and their state of repair, has considerable effect on the working costs.

Detailed investigation into railcar diesel engines.

The engines used vary from the lowest powers up to 450 H.P.

The smaller powered engines, under 120-H.P. motor lorry engines, although thoroughly satisfactory as the result of several years' development, are not powerful enough except for a few very light four-wheeled railcars for services on secondary lines.

The engine builders have therefore specially designed engines for rail motor car use. They have either increased the power of existing designs by increasing the number of cylinders (C.L.M. - GANZ - M.W.M. - M.A.N.), or introduced entirely new designs.

Generally speaking, these engines behaved well, as they incorporate the experience of builders engaged on similar work.

The increase in the number of cylinders is limited by the available space, a matter of great importance in railcars, in which the more room is taken up by the engine, the less there is for the passengers and luggage. The builders have had to consider new designs of engines with the cylinders in two banks such as the V-type or the square-type engine.

In the V engine, the two groups of 6 cylinders, at an angle of 60° to one another, drive a common crank shaft (220, 265 and 500-H.P. Renault — 410-H.P. Maybach — 300, 450-H.P. Mercedes-Benz — 160-H.P. Brno Kralovopolska).

In the square-type engine, the cylinders arranged in two parallel lines drive two crank shafts which in turn drive a central shaft usually coupled to the generator of an electric transmission (420-H.P. M.A.N.).

Although, owing to insufficient experience, it is not possible to come to any final conclusions on these engines, these designs do, however, provide a way whereby the power can be increased, whilst keeping the engine within the space available in a rail motor vehicle.

Some builders, to make it easier to house the engine, have arranged the cylinders horizontally, either on one side or on both sides of the crank shaft (flat twin), so that it can be put under the floor of the vehicle (150-H.P. Cesko-Moravska-Kolben-Danek (fig. 5); 180-H.P. Deutsche Werke; 200-H.P. Vomag; 120-H.P. Skoda).

A) *Nature of engine parts and materials they are made of.*

As regards materials, high-tensile steels are used to a remarkable extent. The crank shafts and connecting rods are made from nickel-chrome, nickel-chrome-molybdenum, or nickel-chrome-tungsten steel.

Duralumin rods are being introduced.

The rods are nearly always I-shaped. The rods for V-type engines are however tubular and are articulated about the big end.

Light-alloy pistons are generally used. Cast iron pistons are still used on the C.L.M. and GANZ engines.

The design of the top of the pistons and the cylinder heads depends on the type of injection and will be dealt with later.

The crank cases are cast iron, steel, or more often light alloy. The design of the 210-H.P. M.A.N. should be mentioned in this connection. The crank case is welded steel, fitted with inspection doors. The liners are dropped into position. The rods, pistons, and even a cy-

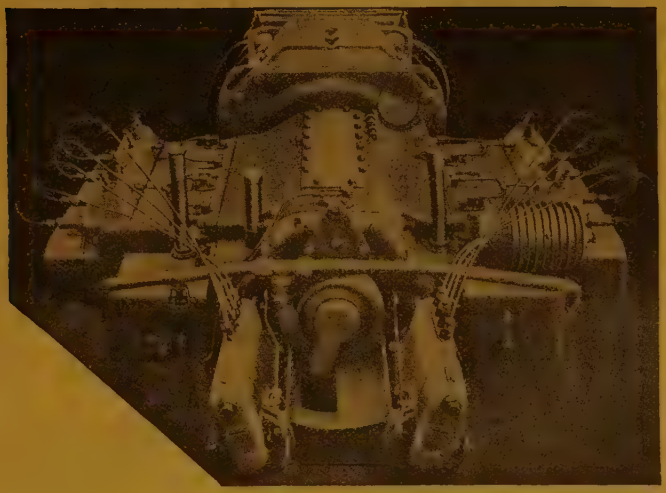


Fig. 5. — C.K.D. 150-H.P. horizontal engine.

linder liner can be removed without completely taking down the engine.

The magnitude and nature of the forces set up in diesel engines have compelled the builders to alter the usual petrol engine layout. The crank shaft bearings are tied to the cylinder head through tie rods, so as to relieve the crank case from traction forces.

The top half of the crank case is stiffened and stayed by ribs which support the bearings.

The bottom half of the crank case only forms the oil reservoir, and carries the oil pumps.

Cylinder block castings are going out, and except for certain engines designed by GANZ and MAYBACH, all the others use liners which are readily replaced, of steel (M.A.N. 210, 280 and 420 H.P.), or more generally of special cast iron.

As the maximum pressures developed in diesel engine cylinders exceed those of the petrol engine, friction about the crank shaft and big end bearings has required particular attention.

Most builders, a few years ago, lined the bronze or steel big and little end and crank shaft bearings with white metal (Hoyt, Synovia); however, owing to certain difficulties experienced, such as breaking away and cracking, through excessive bearing pressures, or to the technical difficulties of applying white metal to steel, there has been a move towards the use of new lead-copper-base alloys melting at 1 000° C. (1 832° F.) (lead-copper metal or lead-bronze). When these anti-friction metals are used, the hardness of the journals must be increased (by local hardening).

MAYBACH alone uses roller bearings throughout; other builders find they set up additional vibrations. SAURER uses them for crank shaft bearings.

The piston pin is either floating, when it is prevented from moving sideways by soft metal discs, or by circlips, or is rigidly held on the piston or rod.

The piston rod small end is fitted either with bronze bushes or with needle bearings (of the NADELLA type).

B) *Lubrication and cooling.*

Pressure lubrication is used in all cases.

In the MAYBACH engine, with roller bearings, a rather special lubrication system has to be used (see fig. 6). The oil from the crank case is driven through the oil filter (1) by the pump (2) into the revolving shaft (3) supported by the crank shaft bearing caps. Each journal on this revolving shaft is drilled so that the hole through the shaft is put into communication with a groove cut in

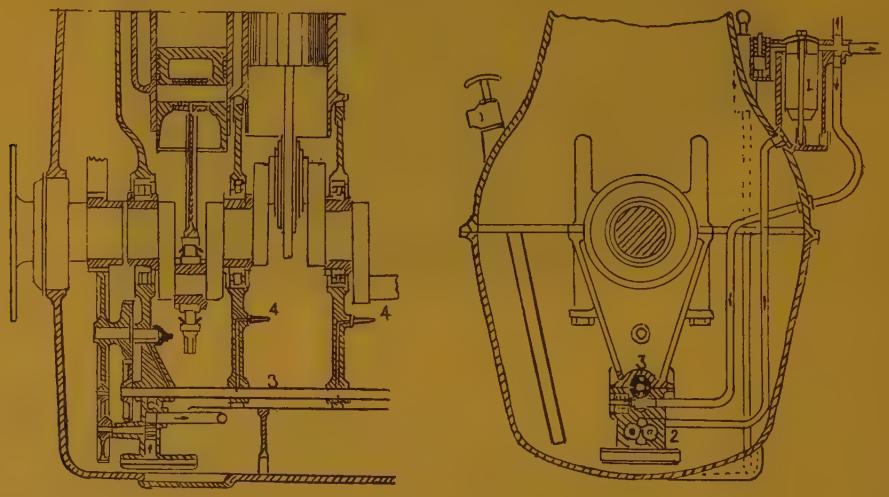


Fig. 6. — Lubrication of MAYBACH engine.

each of the bearing caps and leading to a spray nozzle (4). The oil is discharged as the big ends pass them. This lubricates the big ends — the little ends, crank shaft bearings, and cylinder walls being lubricated by the oil thrown off the big ends.

In the other types of engine (fig. 7), the oil is forced under pressure by a pump (1) into the crank shaft through a passage which feeds the crank shaft bearings. The oil leaves the crank under pressure and lubricates the big ends (3) and, by splash, the little ends and cylinder walls.

Some builders, M.A.N., M.W.M., MERCEDES-BENZ and GANZ, lubricate the little end bearings under pressure. The oil from the big end passes either through a hole drilled in the rod or through a small tube fastened to the rod.

In the case of the GANZ engine, a large quantity of oil is discharged on to the underside of the piston head to cool it.

The majority of builders use the bottom of the crank case as the oil reservoir and fit one or several filters in the oil circuit. On certain engines built by C.L.M., MERCEDES-BENZ, M.W.M., and the ACIÉRIES DU NORD (ACENOR engine, under M.A.N. licence) and M.A.N., the dry sump system is used, i.e. the oil as it drops onto the sump is forced by one or several pumps through the filters and a cooler into an auxiliary reservoir from which another pump forces it under pressure through the lubrication system.

On some engines, such as the 220- and

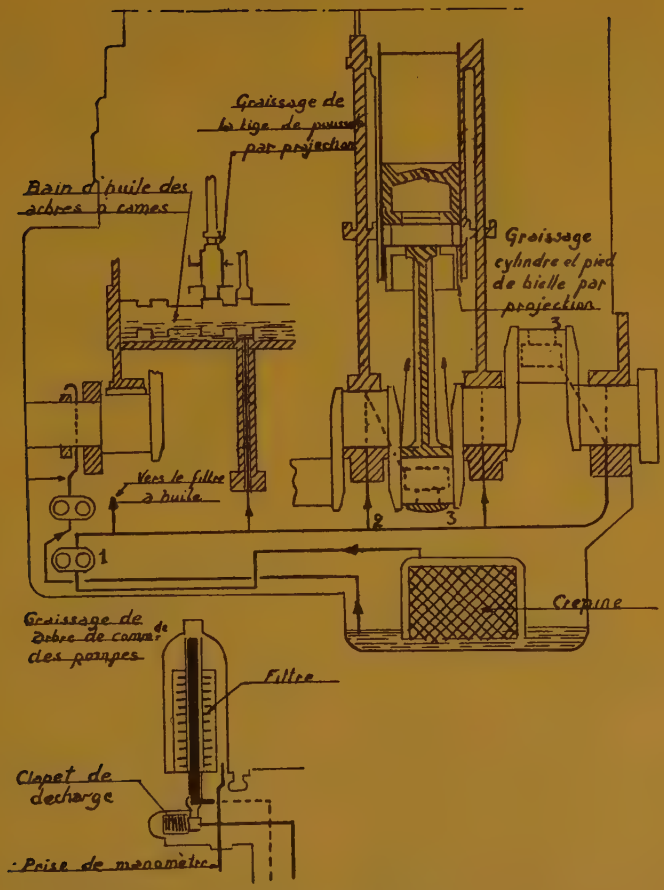


Fig. 7. — Lubrication of 100-H.P. RENAULT engine.

Explanation of French terms:

Graissage de la tige de poussoir par projection = Splash lubrication of tappet rod. — Bain d'huile des arbres à cames = Oil bath of cam shafts. — Graissage cylindre et pied... = Splash lubrication of cylinder and small end of connecting rod. — Vers le filtre à huile = Towards oil filter. — Graissage de l'arbre de commande des pompes = Lubrication of pump shaft. — Crépine = Strainer. — Clapet de décharge = Drain clap valve. — Prise de manomètre = Pipe towards pressure gauge.

265-H.P. RENAULT, and the GANZ, on which the bottom crank case is the oil reservoir, an oil cooler is fitted, either separated from or built into the engine, and the cooling water runs through it.

The cam shafts and auxiliary controls are lubricated as a rule by oil circuits branched off the main pressure line. Some builders lubricate the rockers under pressure and others leave the driver to do it by hand.

Experience has proved the necessity for filtering and even centrifuging the engine lubricating oil.

The designers, whilst improving the lubrication of the different parts of the engine, are now endeavouring to use the oir for cooling purposes. Much has still

to be done to develop a satisfactory lubrication system with an oil which will retain its qualities for a long time and be used all the time at the best temperature, of some 80° C. (176° F.).

* * *

All the engines are water-cooled The radiators are cooled either by the vehicle moving or by forced ventilation (fan driven by the engine) or by a combination of both methods.

The engines are usually fitted with thermostats or similar devices which control the water circulation and, by bypassing part of it, maintain the temparature of the water leaving the engine at about 80° C. (176° F.).

C) *Injection and fuel pumps.*

The different engines we have to consider use one or other of the two systems of injection now employed : « air » or « pump ».

In spite of its good features as regards combustion, and therefore regularity of running, air injection is only used in the case of the 175-H.P. MAYBACH engine. This system is not used more generally because of the complication and weight and the room taken up by the compressor and air bottles.

As the injection area can be set proportionately to the quantity of fuel and the injection pressure to the number of revolutions (regulating the compressor directly driven by the engine), with this system the engine can be arranged to meet all power and speed conditions. In other words, the combustion is good and the engine is very flexible, which are great advantages in the case of traction engines.

All other builders use mechanical injection. The different designs used can be classified into three main groups :

1. *Direct injection.*

Used by the C.L.M., RENAULT (fig. 8), ACIÉRIES DU NORD, M.A.N., MAYBACH (fig. 9), CESKO-MORAVSKA-KOLBEN-DANEK, BRNO KRALOVO POLSKA, 300-H.P. SAURER (under construction), 150-H.P. SAURER.

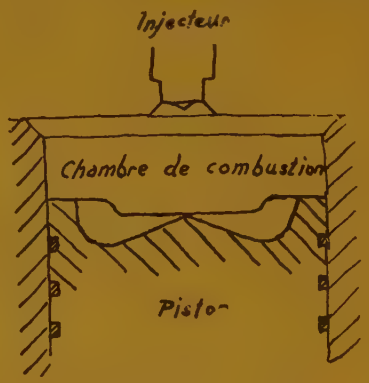


Fig. 8. — RENAULT engine.

The fuel is injected into a compression chamber of more or less compact form, into which the whole of the combustion air is stored at the end of the compression stroke. The form of the piston is so designed as to create turbulence which will promote good combustion.

The injector may be placed either vertically, or horizontally, or again obliquely, and the shape of the jet varies with the position of the injector.

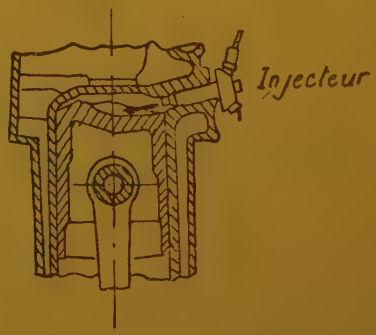


Fig. 9. — MAYBACH engine.

The special design adopted by Messrs. SAURER in all their engines, in which the turbulence is helped by using valves with

deflectors, giving the air a spinning motion about the centre line of the cylinder, and by a compression chamber in the piston, which gives the air a rotary motion round a horizontal axis (fig. 10) should be noted.

The following are the results obtained from a SAURER B X D engine with this

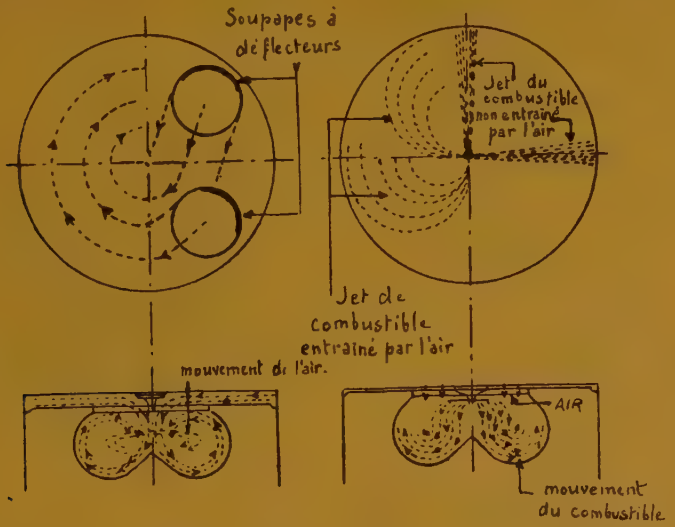


Fig. 10. — Special arrangement now adopted in SAURER engine.

Explanation of French terms:

Soupapes à déflecteurs = Valves with deflectors. — Jet de... par l'air = Fuel jet entrained by the air. — Mouvement de l'air = Air motion. — Mouvement du combustible = Fuel motion.

new arrangement, compared with a B X D of the same bore, stroke and number of revolutions, but with the air chamber mentioned hereafter :

	Maximum power.	Nominal power.	Specific consumption.
Engine with air chamber	160	140	205
Direct-injection engine described above . .	180	150	170

Direct injection is simple. For good combustion the fuel must be finely divided and be perfectly distributed throughout the combustion space under all running conditions.

This means injection pressures of 120 to 400 kgr. (1 700 to 5 700 lb. per sq. inch) with the following attendant drawbacks :

a) rapid wear of pump parts subject-

ed to as much as 120 to 400 kgr./cm² (1 700 to 5 700 lb. per sq. inch) pressure and on which no play can be allowed, and

b) the fuel oil has to be forced through extremely small orifices with the possibility of their choking up or the area of the orifices varying.

2. *Precombustion chamber.*

Used by GANZ (fig. 11), MERCEDES-BENZ (fig. 12), M.W.M., LORRAINE, BRNO-KRALOVO-POLSKA, A.E.C. (Breda licence).

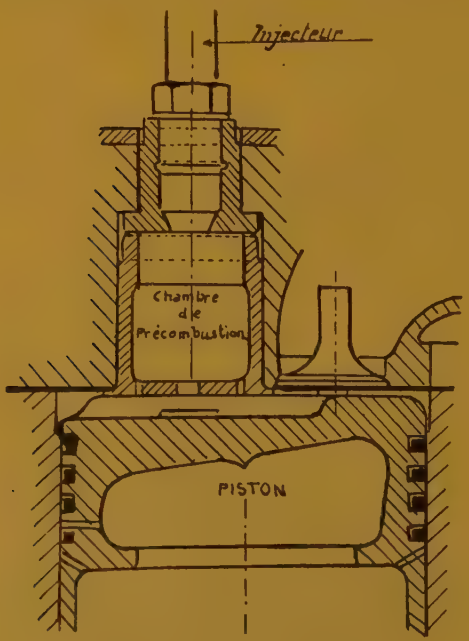


Fig. 11. — GANZ engine.

The fuel is injected into a precombustion chamber which opens in the compression space through a passage of varying form. The temperature, pressure, and composition of the gases in this precombustion chamber at the moment of injection depend on the proportions of the chamber and of the communicating passage. The fuel begins to burn and the chemical changes to start in this chamber. The ensuing rise of pressure forces the mixture through suitably arranged and proportioned nozzles. This system claims to add, to the advantages of mechanical injection (details are light and take up little room), an air injection effect (better pulverisation and greater flexibility under different operating conditions).

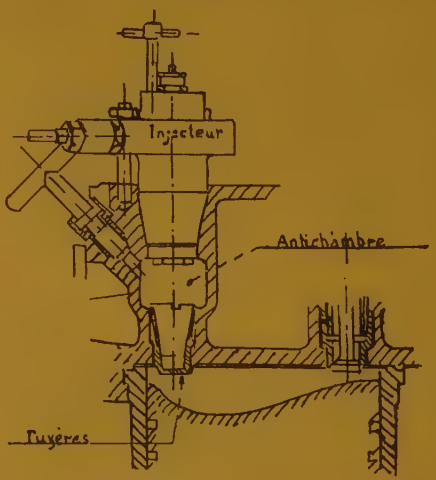


Fig. 12. — BENZ engine.
Precombustion chamber.

Note: Antichambre = Precombustion chamber.
Tuyères = Nozzles.

Mechanically speaking, with this system much lower pressures [60 to 70 kgr. (850 to 1 000 lb. per sq. inch)] can be used, pump wear is reduced and the injectors have larger orifices less likely to choke up.

It should be noted that, owing to the injection first taking place into the precombustion chamber, which is surrounded by a fairly large mass of metal, and wherein the compression pressure is less than in the cylinders, a sufficiently high temperature cannot be obtained to start from cold properly. This difficulty is overcome by such means as a heating plug or a nitre-impregnated wick.

In the Ricardo head used on the English and Italian A.E.C. engines, the whole of the air at the moment of injection is imprisoned in a precombustion chamber of spherical form connected to the cylinders, the clearance volume of which is reduced to the minimum by using a simple hole (fig. 13).

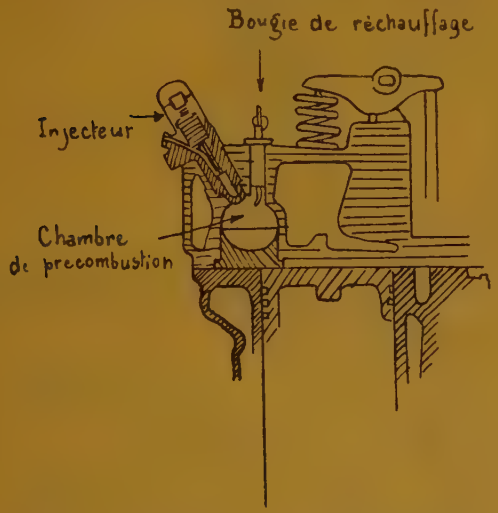


Fig. 13. — The RICARDO precombustion chamber.

Note: Bougie de réchauffage = Heating plug. — Injecteur = Injector. — Chambre de précombustion = Precombustion chamber.

3. *The air chamber* as used on the old SAURER engine and the BERLIET engine (fig. 14), in which it is incorporated in the piston. In this type of engine, a reserve of air is held in a chamber. As soon as the injection ceases, the pressure in the cylinders falls as the expansion has begun, and this reserve air issuing through the orifice completes the combustion which it activates by a scrubbing action.

This system gives a fuller, slower, and more progressive combustion than the direct injection method. The injectors are the same in both cases, the pressure being about 120 kgr./cm² (1 700 lb. per sq. inch).

In all three systems of mechanical injection described above, the top of the pistons and the cylinder heads are of various shapes, selected to give better combustion.

Although many and ingenious designs have been got out, there is still room for much progress.

The designers are endeavouring to obtain good pulverisation of the fuel at all speeds and loads. This is only possible when the injection pressure, the advance of the injection, the degree of turbulence, etc... are in agreement under all operating conditions.

The injectors are either of the open type (C.L.M., fig. 15, GANZ) or with obturating needle valves on most of the engines. In the latter case the needle held on its seat by a spring is lifted by the pressure of the fuel (fig. 16).

The designers have experienced much difficulty in preventing reflex pressure waves from opening the injector a second time without control. They have overcome the difficulty by suitably proportioning the injectors and piping.

* * *

The fuel pumps are designed to maintain constant pressure from the start to the end of the injection period. The injection is arranged to begin and end suddenly.

The suction and discharge orifices are opened and closed in the BOSCH (fig. 17), C.L.M... pumps by the piston acting as distributor, the quantity of oil injected being controlled by the rotation of the piston; the P.M. (mechanical pressure) pump is adjusted in the same way, but an incline on the top of the piston varies the start of the injection in terms of the quantity of fuel injected. In the M.A.N. pump the discharge only is controlled by the piston, an automatic suction valve being fitted.

In some instances the injection is stopped by a release valve opening (Deckel pump used on the Maybach engines).

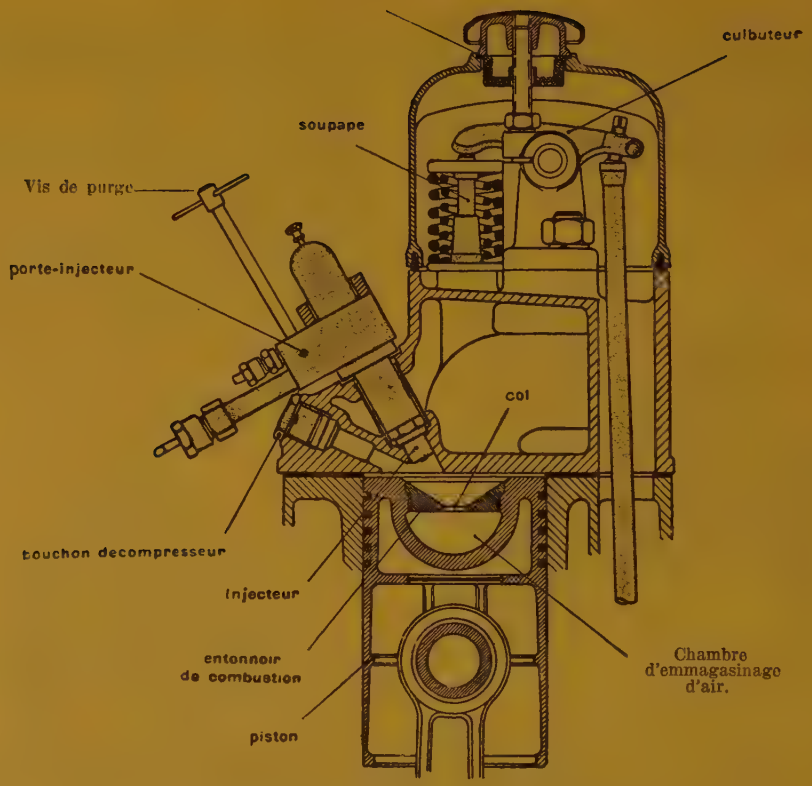


Fig. 14. — Air chamber of BERLIET engine.

Explanation of French terms:
Culbuteur = valve rocker. — Soupape = valve. — Vis de purge = waste oil screw. — Bouchon décompresseur = compression relief valve. — Entonnoir de combustion = combustion space. — Col = passage. — Chambre d'emmagasinage d'air = air chamber.

An attempt has been made in the GANZ pump (fig. 18) to render the injection pressure independent of the speed of rotation. The injection is due to the pressure of a spring which is compressed by a cam and suddenly released. The quantity of fuel being injected is varied by altering the stroke of the piston.

D) *Governing.*

A governor is more necessary with the diesel engine than with either steam or petrol engines.

It has to meet the following two cases:

1. — If there were nothing to control the air and fuel supply, the engine under certain conditions could run at speeds above the normal;

2. — At a given speed, as the volume of air in the cylinders is incompletely consumed under normal working conditions, the engine can develop a power exceeding the designed value, were more fuel to be injected.

The speed governors are based on centrifugal force and act directly (BOSCH governor, fig. 19) or control through oil under pressure (MAYBACH engine) the quantity of fuel oil injected. This action

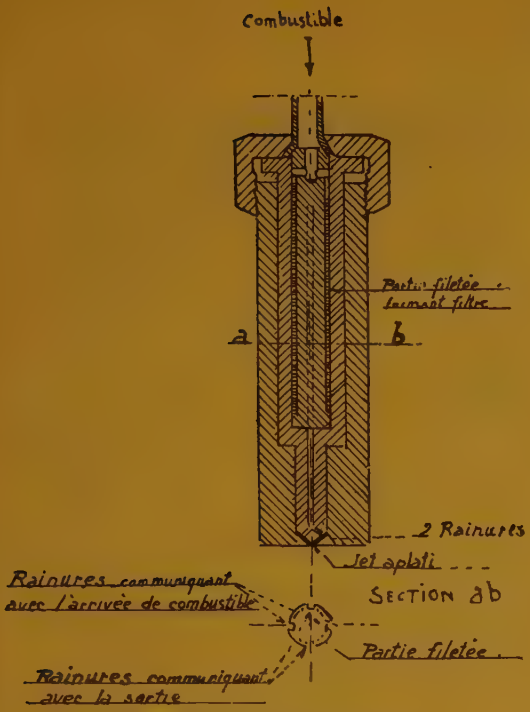


Fig. 15. — C.L.M. injector.

Explanation of French terms:

Combustible = Fuel intake. — Partie filetée formant filtre = Threaded part acting as a filter. — 2 rainures = 2 grooves. — Jet aplati = Flattened-out jet. — Rainures communiquant avec l'arrivée du combustible = Grooves communicating with fuel intake. — Section = Cross section. — Rainures communiquant avec la sortie = Grooves communicating with outlet.

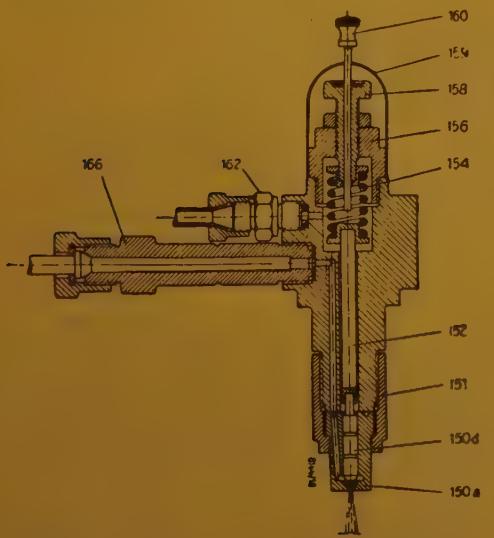


Fig. 16. — Injector with obturating needle valve.

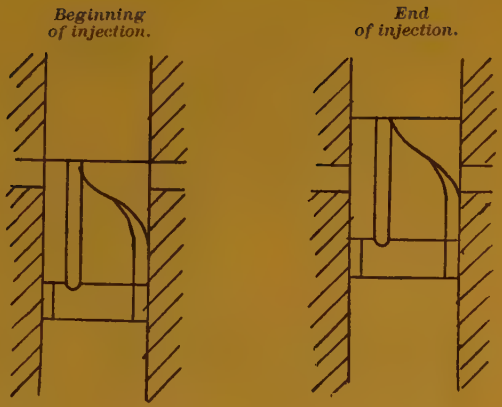


Fig. 17. — Working of Bosch injection pump.

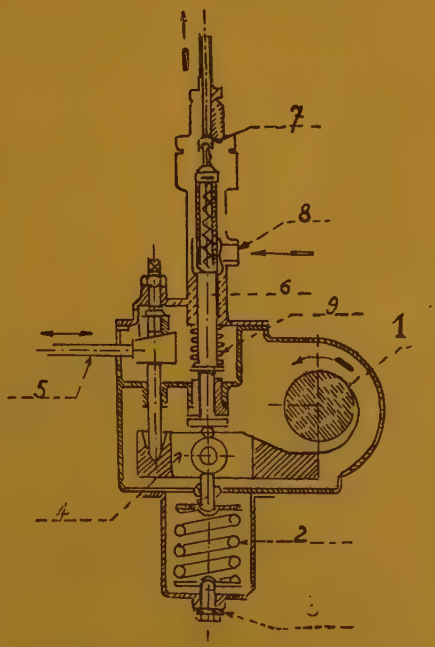


Fig. 18. — Ganz injection pump.

Explanation:

1. Cam.
2. Thrust spring
3. Adjustment of spring.
4. Lever.
5. Control of injection.
6. Piston.
7. Retaining valve.
8. Intake.
9. Piston release spring.

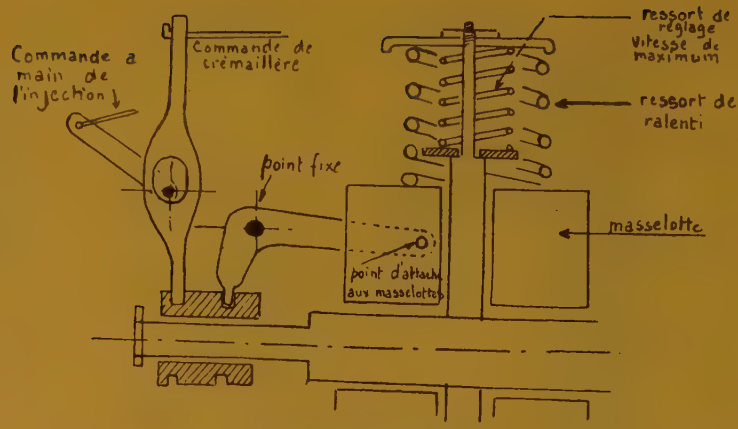


Fig. 19. — Diagram showing the principle of the BOSCH governor.

Explanation of French terms:

Commande à main... = Injection control handle (manual). — Commande de crémaillère = Rack control. — Ressort de réglage... = Adjusting spring for maximum speed. — Ressort de ralenti = Idling speed spring. — Point d'attache aux masselottes = Fastening point to fly-weights.

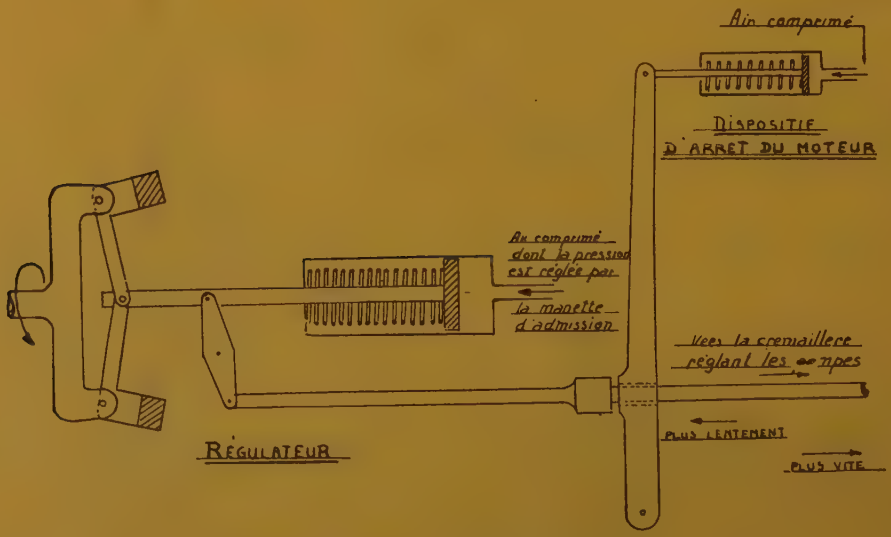

Air comprimé
DISPOSITIF D'ARRÊT DU MOTEUR
Air comprimé dont la pression est réglée par la manette d'admission
Vers la crémaillère réglant les injecteurs
RÉGULATEUR
PLUS LENTEMENT
PLUS VITE

Fig. 20. — Speed governor and stopping device for M.A.N. engine.

Explanation of French terms:

Air comprimé = Compressed air. — Dispositif d'arrêt du moteur = Engine stopping device. — Air comprimé dont la pression... = Compressed air the pressure of which is adjusted by the inlet lever. — Régulateur = Governor. — Vers la crémaillère = Towards pump controlling rack. — Plus lentement = Slowing down. — Plus vite = Faster.

is governed by the accelerator control which acts either on the governor spring or by levers on the pump operating rods, either directly or by compressed air (M.A.N., fig. 20).

These governors allow a variation of about 5 % to 10 % between the maximum speed at full load and light.

To meet the second condition a stop is fitted in the pump to fix the maximum quantity of oil injected.

E) *Lightening the diesel engine. Use of supercharging.*

In this respect, the important characteristic is the weight per H.P. We have drawn up table III classifying these en-

TABLE III.

NAME.	Engine H. P.	Weight per H. P.		Nominal speed r. p. m.
		Kgr.	(*Lb.*)	
GANZ	110	17.5	*38.6*	1 000
GANZ	125	16	*35.3*	1 000
M. W. M.	175	15.7	*34.6*	800
M. W. M.	125	14.4	*31.7*	1 000
ACENOR, M. A. N. licence	170	13	*28.7*	900
CESKOMORAVSKA-KOLDEN-DANEK	350	12.5	*27.6*	900
BRNO-KRALOVO POLSKA	160	12.5	*27.6*	1 300
DELAUNAY-BELLEVILLE, KRUPP lic.	65	11.8	*26.0*	1 000
M. A. N.	190	10.8	*23.8*	1 000
RENAULT 100 H.P.	100	10	*22.0*	1 500
BERLIET	125	9.4	*20.7*	1 500
M. A. N.	150	8.9	*19.6*	1 500
GANZ	220	8.4	*18.5*	1 200
SAURER	140	8.3	*18.3*	1 500
GANZ	130	8.1	*17.9*	1 350
GANZ	95	8.1	*17.9*	1 650
C. L. M.	100	8	*17.6*	1 500
MAYBACH	210	7.9	*17.4*	1 400
M. A. N.	420	7.5	*16.5*	1 400
MERCEDES-BENZ	135	7.4	*16.3*	1 700
RENAULT	220	7.1	*15.7*	1 500
C. L. M.	80	7.1	*15.7*	1 500
M. A. N.	210	7.1	*15.7*	1 400
LORRAINE	120	6.8	*15.0*	1 500
MAYBACH	175	6.3	*13.9*	1 400
MERCEDES-BENZ	300	6	*13.2*	1 500
MAYBACH	410	4.9 (1)	*10.8* (1)	1 400

(1) Weight of engine without clutch, nor flywheel, nor starter.

gines according to this ratio, and giving the normal r. p. m. of each.

Weight reduction can be obtained in several ways :

1. Increasing the engine speed (r.p.m.).

When engines of like design are examined, it will be seen that increased speed reduces very appreciably the weight per H.P.

The metallurgists have put at our disposal materials of such qualities that,

DESIGN.	Engine H. P.	Weight per H. P.		Nominal speed r. p. m.
		Kgr.	(*Lb*)	
M. W. M.	170	14.4	*31.7*	800
ACENOR (M. A. N.)	170	13	*28.7*	900
M. A. N.	190	10.8	*23.8*	1 000
M. A. N.	150	8.9	*19.6*	1 500

in conjunction with the improvements in design, speeds of over 1 500 r. p. m. for engines of about 125 H.P. are now possible.

Great improvements in the methods of injecting the fuel had to be made before such speeds were possible. The inertia of the pumps, fuel oil in the pipes, and injectors, had to be overcome, apart from the difficulty of ensuring combustion in about 1/500th of a second.

As two other engine factors, the lineal speed of the pistons (linked up with the speed of rotation) and the mean effective pressure, are increased, the weight per horse power falls. Lubrication difficulties, kinematic forces, and the strength of the parts appear at the present time to make higher speeds than 10 m. (32.8 feet) per sec. and a mean effective pressure of 7 kgr./cm² (100 lb. per sq. inch) impracticable.

2. Use of the 2-stroke cycle.

Further reduction in engine weight can be obtained by using two-stroke cycle engines as they give 1.8 greater power than a four-stroke cycle engine of equal cylinder volume. This advantage also affects the space taken up. Moreover the two-stroke engine also has a simpler valve gear and has other good features, owing to the scavenging (the burnt gases are well swept out, there is slight supercharge, and the cylinder temperature is slightly reduced).

Practical difficulties (effective scavenging, high stresses in parts) are limiting the development of this type of engine, the JUNKERS (French licensee, C.L.M. Willème) and the BURMEISTER & WAIN (Belgian National Rys. Co.'s railcars) being the only ones at present used on railcars.

The JUNKERS two-stroke engine has cast iron pistons and weighs 7.1 kgr. (15.65 lb.) per H.P.; by the use of two opposed pistons, the fatigue of the parts is overcome very neatly.

3. Use of light metals.

The lightening made possible by specially designing the parts must not be overlooked. Either light metals can be used to the fullest extent, or steel and welding be used throughout the engine. In this way, the weight of the 210-H.P. M.A.N. engine has been reduced to 7.1 kgr. (15.65 lb.) per H.P.

4. Supercharging.

Several builders are trying to lighten the engines by supercharging. Supercharging mainly consists in supplying the air to the diesel engine under some compression, instead of the engine drawing it in.

The result is :

1. the cylinder is better filled through the scavenging of the burnt gases under the action of the fresh air;

2. greater weight of air admitted, due to the higher pressure and also the greater cooling of the cylinders. The quantity of fuel injected can thereby be increased and be better burnt, resulting in the thermo-dynamic efficiency of the engine being raised.

As an example, the ordinary 410-H.P. Maybach engine weighs 2 100 kgr. (4 630 lb.). Supercharging increases the weight by 300 kgr. (661 lb.), and the H.P. by 190; the weight per H.P. becomes 4 kgr. (8.8 lb.) instead of 4.7 kgr. (10.36 lb.).

In addition to this weight saving, the water cooling equipment is also lighter. The quantity of heat units taken away by the supercharging air is considerable, and the quantity of heat units to be carried off by the cooling water is lowered by as much, which means smaller or at least equivalent radiators for higher a power developed.

The table below gives the results obtained on a locomotive diesel engine

	Absolute units.		Relative figures.	
	Heat units removed by the water.	Heat units removed by the exhaust.	Heat units removed by the water.	Heat units removed by the exhaust.
700-H.P. non-supercharged engine	320 000	400 000	26 %	32.5 %
950-H.P. supercharged engine	245 000	720 000	15 %	44 %

developing 700 H.P. at 4 700 r.p.m., built by the S.G.C.M. and supercharged up to 950 H.P. by means of a RATEAU turbo-blower.

Supercharging is obtained by means of very small and light turbo-blowers driven by the exhaust gases and turning at speeds ranging about 10 000 r.p.m.

In order not to overstress the supercharged engine, the builders have been obliged not to exceed the maximum pressures obtained in non-supercharged engines, in spite of the great quantity of fuel injected; this has been done by a slight reduction of the compression and by considerably reducing the advance of the injection.

During supercharging tests, it was found that the indicator diagram was much fuller (higher mean pressure) and that the rise of the pressure was much steadier.

So far, supercharging diesel railcar engines has not got beyond the trial stage, and experience alone will show if the turbo-blowers will stand up to the heavy duty required in railcar work.

F) *Fuels.*

In slow-running diesels, any kind of fuel can be used. When high-speed diesels came on the market the fuels had to be carefully investigated so as to ascertain within narrow limits those suitable for present-day engines, naturally keeping in mind the need for improving the engine step by step, so that the middle range of fuels obtained by distilling mineral oils can be burnt without difficulty.

One important fuel characteristic is ignition lag which should be as small as possible to prevent the engine knocking. The ignition lag is inversely pro-

portional to the cetene number. In France at the present day there is a tendency to include the cetene number in the specification and to require fuels having a 45 to 50 cetene number as a minimum.

G) *Mounting and taking down the engine.*

The engine can be carried in the body or on the bogie; practically, both methods have been used by the builders to the same extent. The first method has the advantage that the engine is out of the dust and is protected from the shocks and vibrations the bogie receives from the track. The control gear and piping are easier to fit, but special care has to be taken to prevent engine vibrations being transmitted to the body. The second solution, in addition to the advantage mentioned above, enables the whole of the engine, gear box, transmission and electric motor to be combined into one compact, interchangeable and easily removable unit. In the case of mechanical transmission, the engine is more easily connected to the axles.

Whichever location is chosen, most builders have devoted much attention to making it easy to take down the engine. The following are some of the methods adopted :

1. removal of the engine through the front of the vehicle without lifting the body (Renault; 32 and 56-seater Michelines; Baudet-Donon-Roussel); or by raising the body a few centimetres (de Dietrich).

2. removal of the engine through the body side (800-H.P. Bugatti).

3. removal of the engine by dropping it (56-seater Michelines, 400 H.P. Bugatti, C.G.C.).

4. removal of the engine through the roof (Finland).

* * *

CHAPTER III.

PART I.

RAILCAR TRANSMISSIONS.

One of the most difficult questions in connection with the use of the heat engine for railcar work is the transmission of the power of the engine from its crank shaft to the wheels of the vehicle. The problem is in fact to provide a liaison between the wheels the speed of which can vary between enormous limits, 0 to 120 km. (75 miles) an hour, for example, and the crank shaft of the heat engine, the number of revolutions of which, for constructional and economic reasons and for durability, should not vary much from an optimum figure.

The system of transmission therefore cannot be a simple mechanical intermediate motion, such as the connecting rods of the steam engine, but must be a true energy converter.

For horse-powers of 100, 200, and even 250 and 300, mechanical transmission appears to be preferred to electric, even though the builders of electric transmissions rightly call attention to the reliability of their material over long periods of work, and the makers of hydraulic transmissions insist on the very high efficiency of their transmission when running on the direct drive.

For such powers the makers of mechanical transmissions claim :

1. lower first costs;
2. lower operating costs;
3. lower repair costs;
4. greater reliability.

1. *Lower first costs.* — *a*) The electrical equipment is more expensive than the mechanical.

b) The power of the diesel engine will have to be increased because the efficiency at full speed of the electric transmission is usually below that of the mechanical transmission, and also because the weight of the equipment of a

railcar with electric transmission is greater than that with a mechanical transmission.

Messrs. GANZ, for example, estimate that the cost of a railcar with electric transmission is 10 to 14 % higher than that with mechanical transmission giving the same power at the rail.

2. *Lower operating costs.* — The cost of fuel, and therefore the traction costs, will be lower with mechanical transmission than with electric transmission; the latter weighs more and at full speed its efficiency is lower.

3. *Lower maintenance costs.* — Builders of electric transmissions claimed, even recently, their low maintenance costs, but the latest mechanical transmissions provide, besides a much higher efficiency at full speed than the electric transmissions, very low maintenance costs, owing to the improvements made in gearing manufacture.

4. *Reliability.* — The experience of the railways operating railcars with mechanical transmission over a number of years is that these vehicles can run several hundred thousands kilometres without any failure in the transmission.

For horse-powers exceeding 300, electric transmission has so far been adopted almost exclusively. The REICHSBAHN, however, has on order several high-power railcars with hydraulic transmission. BELGIUM is building railcars of over

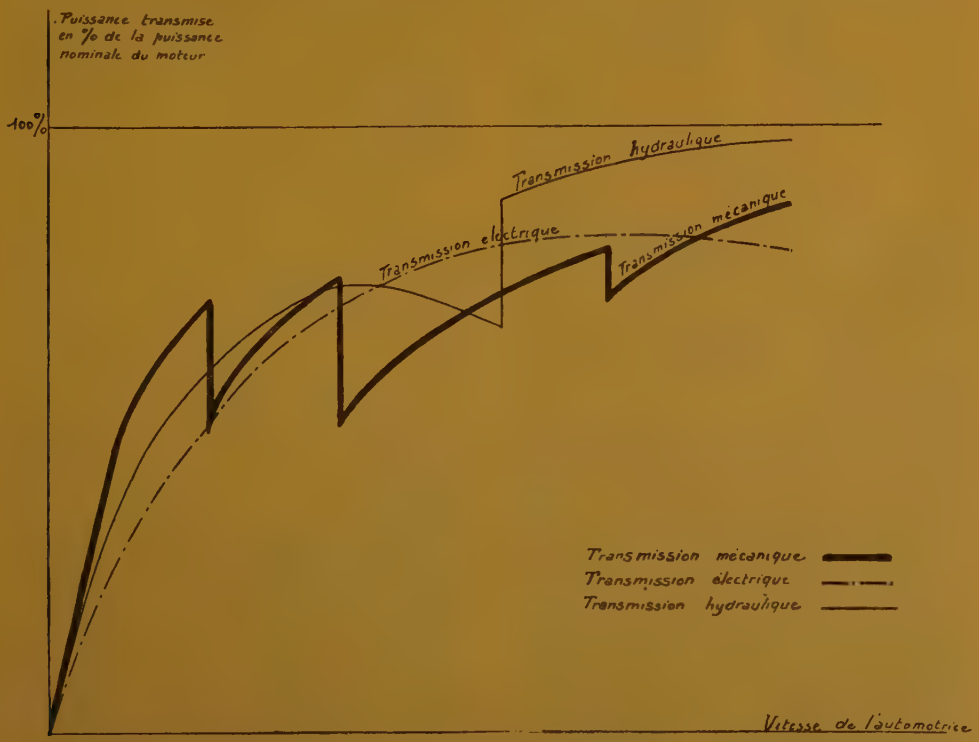


Fig. 21 showing how the different transmissions make use of the engine power.
Note: Puissance transmise... = power transmitted, as a per cent of the nominal engine power.
Vitesse de l'automotrice = railcar speed.

300 H.P. with mechanical transmission, and Messrs. RENAULT have under consideration 500- and 1 000-H.P. railcars with mechanical transmission.

Some builders consider the hydraulic as the transmission of the future for high-power railcars.

It would be premature to come to any conclusion on the merits of these gears at present. It should be noted, however, that a good transmission gear ought to enable the driver to control it from a distance, without any physical effort. In this connection it will be shown hereafter that the builders of all three forms of drive have designed satisfactory distant-operated controls, some of which have solved the problem in a remarkable manner.

Before describing the different forms of drive, we think we should make a few general remarks on the way these transmission gears make use of the engine power at different railcar speeds.

As shown by the diagram (fig. 21), with electric transmission the power curve is very regular and increases with the speed to a certain maximum, after which it generally falls off. The mechanical transmission is seen to give sudden changes in power as the gear is changed. The hydraulic transmission shows a great variation in the power transmitted when going over from the converter to direct drive.

These curves clearly show that a better efficiency should not be claimed off hand for a given transmission as compared with another. For two given forms of drive, the efficiency depends entirely on the speed of the railcar. In practice, we should take the efficiency over the starting period, or the efficiency at the maximum engine speed. When dealing with the efficiency over the starting period, we must be careful to take into account lost time (time lost through declutching or slipping the clutch, etc...), when changing gear in the case of mechanical transmission, or for coupling in the case of hydraulic transmission.

The aforementioned diagram is schematic and any general conclusions, such as that at maximum speeds the mechanical transmission has a higher efficiency than the electric, must not be drawn from it. There are cases which are just the contrary.

* * *

PART II.

MECHANICAL TRANSMISSIONS.

1. General.

The different systems of mechanical transmission used on railcars include as a rule the following parts after the engine :

clutch,
gear box,
reverse gear,
drive of one or more axles.

These parts are usually connected by shafts with suitable joints, or, but more rarely, by chains. Their respective position naturally depends on the type of railcar.

Mechanical transmissions differ considerably in layout according as they are for four-wheeled or bogie vehicles. They vary again in bogie vehicles according to the position of the engine : on the bogie or on the main frame. It will nonetheless be possible to describe hereafter a number of parts which may be common to most railcars with mechanical transmission.

In some cases the transmission gear and engine are in one unit (RENAULT), which is easily removed for repairs.

When a railcar is not reversible, no reverse gear is fitted, but instead, an additional speed in the gear box.

In some designs of gear box, each

train of gears is fitted with its own clutch (MAYBACH) or acts as a separate clutch (WINTERTHUR), the main clutch in this case being as a rule left out.

Occasionally the following devices are included in mechanical transmissions :

free wheel,
differential,
constant-ratio speed-reducing gear.

* * *

General remarks on each part of the transmission are given below.

Clutch.

Nearly all clutches are of the multiple dry-plate type usually used in automobile practice. When the clutch is in, the discs are held together by coiled springs arranged in parallel to the centre line of the transmission. The clutch is operated mechanically or by compressed air.

In some cases the clutch pedal also operates a so-called clutch brake, which acts on the driven shaft.

Gear box.

There are two principal types of gear box :

1. constant-mesh gears;
2. sliding gears.

In the first type, each train of gears consists of a wheel keyed to its shaft, and another wheel free on its shaft. The loose wheel can be coupled to its shaft by a dog (FIAT) or a separate clutch (GANZ). When a dog is used, the dog and the gear are brought to the same speed before they are meshed together. This is called synchronised gears. The dogs are operated mechanically or pneumatically.

When there is a separate clutch for each train of gears (T.A.G.) the clutch is usually of the disc type, compressed-air or pressure-oil operated.

In connection with constant-mesh gear boxes, certain boxes making use of the valuable properties of epicyclic gears should be mentioned. In such boxes, one element of the train of gears giving the desired speed is held stationary, either by an electro-magnetic clutch (COTAL) or by a mechanical brake (WILSON).

The sliding-gear boxes are of the automobile type, the gears being changed mechanically or pneumatically. Such boxes are used on the lowest-powered railcars (SKODA, Czechoslovakia).

As the gear box is heavy and costly, the design is based on the torque and not on the power to be transmitted. High-speed engines should therefore be preferred so that at equal power the torque is as small as possible. The speed of the engine however also affects its weight and, therefore, the weight of the rest of the railcar, thereby increasing the weight to be hauled, and reducing the maximum speed possible for a given power.

Reverse gear.

Two main types are used :

1. Bevel gears (cf. fig. 22) consisting of a bevel pinion driven by the engine and constantly in mesh with two bevel wheels mounted loose on their own shaft, which is at right angles to the shaft carrying the pinion. A mechanically or pneumatically-operated dog slides on the cross shaft and couples this shaft to one or other of the two bevel wheels. In this way the driven shaft is driven in the desired direction.

2. Reverser using idler gears (cf. fig. 23) in which the power is transmitted to the driven shaft either directly by two straight gears for forward running or through one or several idler wheels which reverse the direction of rotation for back running. The reverse gear is fitted either in front or behind the gear box, and in some cases is combined with the gear box. It is as a rule built in with the axle gear.

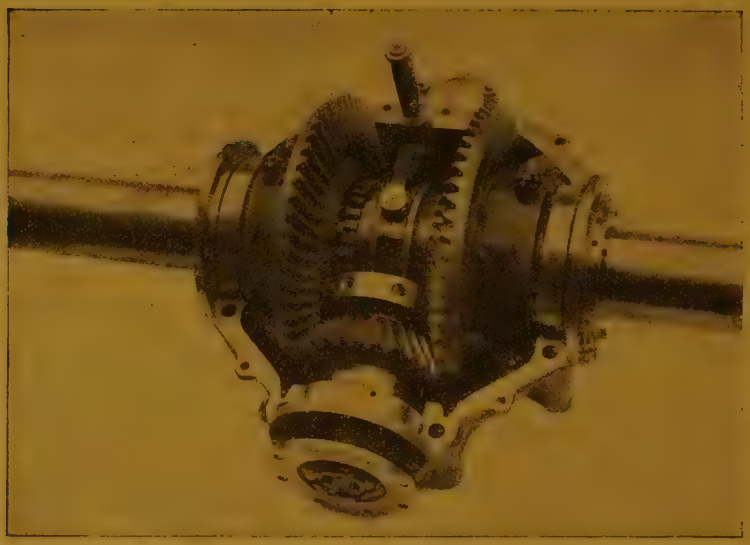


Fig. 22. — Reverse gear with bevel wheels, of the MYLIUS transmission.

Axle drives.

The power is usually transmitted to the wheels by pairs of bevels.

In some cases, such as the MAYBACH-RENK, the engine crank shaft drives a loose axle by connecting rods.

Finally, some builders (B.D.R.) use chains to drive the axles by sprocket wheels keyed on the axles.

Free wheel.

A free wheel device is fitted on some railcars; the vehicle can then be run down gradients without the engine being driven by the transmission. This device protects the engine and isolates it from the transmission in the event of misuse of the gear.

* * *

Below is given a brief description of a certain number of mechanical transmissions on railcars now in service. Constant-mesh gear boxes will be described first, and then those with sliding gears.

2. Transmissions with constant-mesh gear boxes.

a) *Skoda transmission.*

The SKODA transmission (fig. 23) used on the railcars built by this firm for the Turkish State Railways consists of :

main clutch,
gear box,
reverse gear,
horizontal cardan shaft driving the axles through bevels.

The main clutch is of the multiplate dry type. In the gear box there are three parallel shafts, the first driven by the engine, a secondary shaft in line with the first, and an intermediate shaft. The three shafts carry four trains of gears always in mesh, giving four speeds.

The reverse gear is embodied in the speed gear box, the drive being taken through a lay shaft.

b) *Mylius transmission.*

The MYLIUS transmission (figs. 24 and 25) consists of :

main clutch,

gear box,
cardan shaft,
reverse gear, and
axle driving gear.

The main clutch is of the multiplate dry type.

The clutch is withdrawn by compressed air.

The Mylius gear box has three main shafts :

a primary shaft driven by the engine,
a driven shaft K, fitted as an extension of the former, and
an intermediate shaft parallel to the two first.

The shafts carry four trains of con-

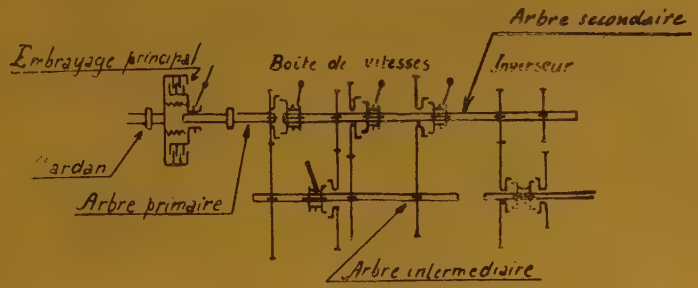


Fig. 23. — SKODA transmission for Turkey.

Explanation of French terms :

Embrayage principal = Main clutch. — Boîte de vitesses = Speed gear box. — Arbre secondaire = Driven shaft. — Inverseur = Reverse gear. — Arbre primaire = Main shaft. — Arbre intermédiaire = Lay shaft.

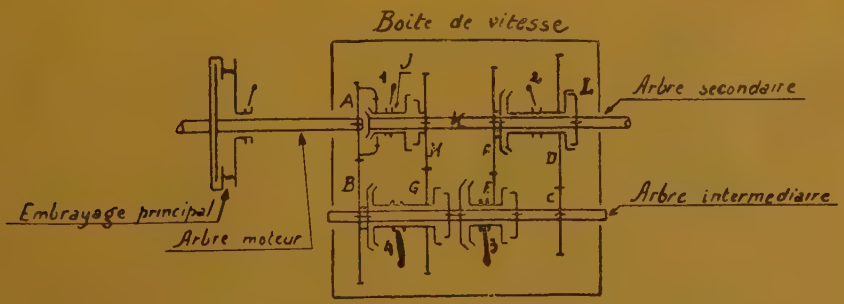


Fig. 24. — MYLIUS transmission. (The reverse gear is not shown.)

stant-mesh gears consisting of pinions A and B, C and D, E and F, G and H.

The pinion A has inside and outside teeth, and is integral with the primary shaft.

Pinions B, C, F and H are keyed to their shaft.

Pinions D, E, and G are free on their shaft and can slide along it. Sleeve J too is free on shaft K and is constantly in mesh with the inner teeth of pinion A.

The sliding pinions and the sleeve J are moved by selector gear with forks 1, 2, 3 and 4.

Each of the loose pinions D, E and G and the sleeve J have, on the left side, a cone friction clutch and, on the right side, a half claw coupling.

Keyed to the driven shaft K there are: on the left end a cone clutch plate, on

Fig. 25. — MYLIUS gear box.

the right end a half claw coupling L, and on the intermediate shaft between wheels E and G a part with a half claw coupling on the left side and a cone clutch plate on the right side.

To engage a particular gear the corresponding loose wheel is moved to the left and this engages the cone plate on this wheel with the corresponding bearing on the keyed wheel on its left, and causes the movable wheel to run at the speed of its shaft. The movable wheel is then moved back to the right and thanks to the speed synchronism so obtained, the claw coupling is easily engaged.

The figure shows the position of the gears for the first speed.

The reverse gear is by bevel gears operated pneumatically.

The complete MYLIUS transmission for 330 H.P. at 1 500 r.p.m. weighs 1 500 kgr. (3 505 lb.).

The firm has already supplied 95 boxes for powers of 50 H.P. and over, and has under construction 125 boxes for powers of from 75 H.P. and over.

This gear is used on railcars of the German State Railways and on the de Dietrich railcars belonging to the French Main-Line Companies.

c) *Transmission using the S.L.M. Winterthur gear box.*

The S.L.M. Winterthur gear box (figs. 26 and 27) usually has four speeds.

Four pinions corresponding to the four speeds are keyed on the primary shaft and are in constant mesh with the corresponding wheels on the secondary shaft.

Each wheel on the secondary shaft is formed of two rings D and includes its own clutch which works as follows :

The hubs of two coupling discs E are mounted on the secondary shaft A and can slide along it, but not turn on it.

The two rings D forming the wheel are loose on the hubs of the two discs E, but cannot move longitudinally.

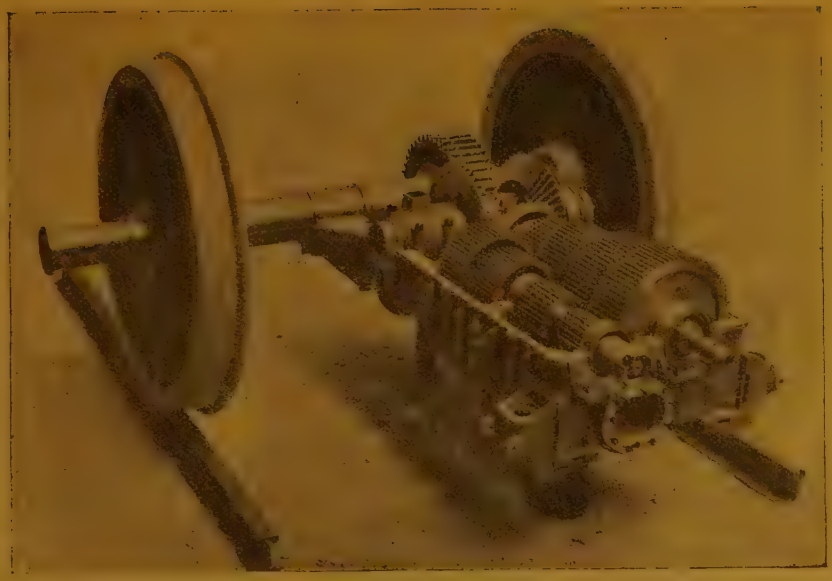


Fig. 26. — WINTERTHUR gear box.

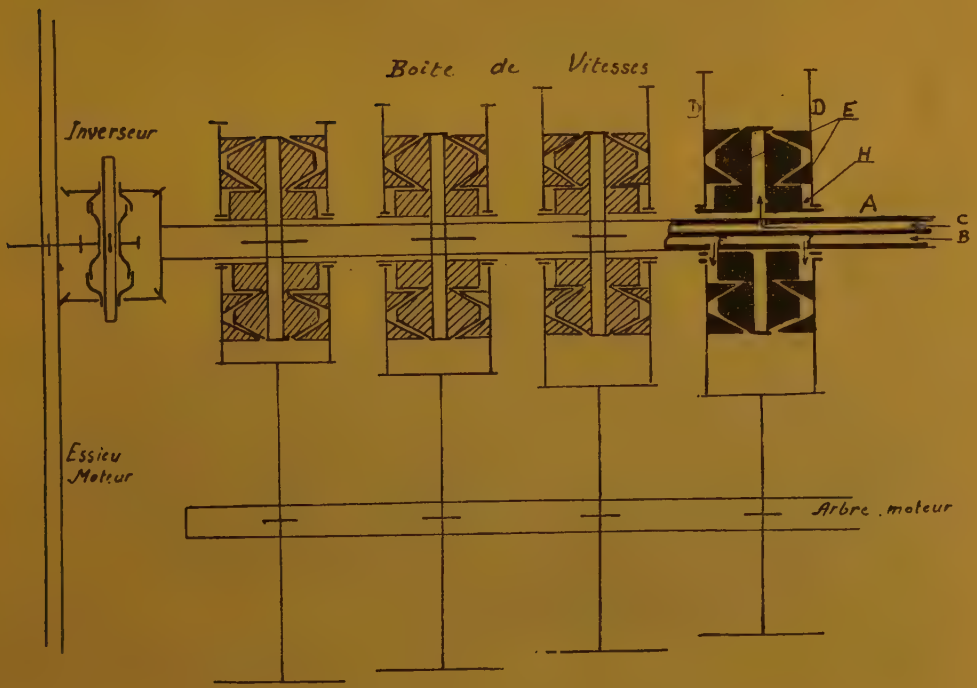


Fig. 27. — WINTERTHUR transmission.

Note: Inverseur = Reverse gear. — Boite de vitesses = Gear box. — Essieu moteur = Driving axle. Arbre moteur = Main shaft.

Circular V-shaped grooves are cut in the coupling discs E and the rings D to fit into one another.

An oil pump driven by the primary shaft supplies oil under pressure to work the clutch.

A distribution valve controls the amount of oil admitted and is so arranged that only one clutch can be worked at a time.

When engaging a gear, the oil under pressure admitted through the passage C of the secondary shaft A penetrates between the discs E and forces them apart until each couples with the corresponding rings D. The secondary shaft is thereby gradually driven by the train of gears considered.

When declutching, the oil between the discs E is exhausted and the discs are forced together by the back pressure of the oil admitted in the chambers H by the passage B and the orifices F and I.

When starting, the oil pressure is reduced so that the first speed is gradually engaged.

The S.L.M. Winterthur four-speed gear box on the Decauville railcar of the French Nord Railway includes, in the same casing, the reverse gear of the usual straight pinion type.

The reverse gear has three parallel shafts. The first is coupled by chain to the second shaft of the gear box, and the third drives the driving axles. The drive is direct in one running direction; in the other there is a wide intermediate wheel. Reversing is obtained by a pneumatically-controlled dog sliding on the third shaft.

On the four-wheeled P.L.M. railcar built by the Compagnie Française de Matériel de Chemin de fer, the S.L.M. Winterthur four-speed box located at the centre of the frame drives the secondary shaft with universal joints which in turn drive the driving axles through bevel gears.

The reverse gear, in the driving axle casing, has bevel gears.

The Winterthur transmission for transmitting 300 H.P. at 1 500 r.p.m. weighs 1 890 kgr. (4 166 lb.) including the reverse gear.

The Winterthur Company has now 100 gear boxes in service, and 54 on order for powers of 150 to 300 H.P.

d) *Fiat transmission.*

This drive has a four-speed constant-mesh gear box; the speeds are engaged by two pneumatically-operated dogs.

The reverse gear is located behind the free wheel, has bevel wheels, and is pneumatically controlled.

The weight of a gear box transmitting up to 120 H.P. at 2 000 r.p.m. is 286 kgr. (630 lb.), including the compressor drive box, the clutch control cylinder and gear case.

The compressor weighs 27 kgr. (59.5 lb.). Messrs. FIAT have now 94 gear boxes in service, for engines of 120 H.P., and 130 boxes under construction, for 75-H.P. and 100-H.P. engines.

e) *Ganz transmission* (fig. 28).

This box gives 5 speeds in each running direction. The gears are always in mesh and are pneumatically operated. The reverse gear on some rail motor cars is of the straight gear type, and in others, bevel wheels are used.

The GANZ transmission gear, with the gear box in Nickalum for 275 H.P. at 1 200 r.p.m., weighs 1 200 kgr. (2 645 lb.) not including the reverse gear.

The same gear with cast iron box weighs 1 500 kgr. (3 300 lb.).

Messrs. Ganz now have 130 gear boxes for 60 to 275 H.P. in service; 61 boxes for 95 to 275 H.P. are in hand.

f) *Maybach transmission.*

The MAYBACH gear box (fig. 29) is controlled by oil under pressure; it has four speeds with four trains of gears, each with its own clutch.

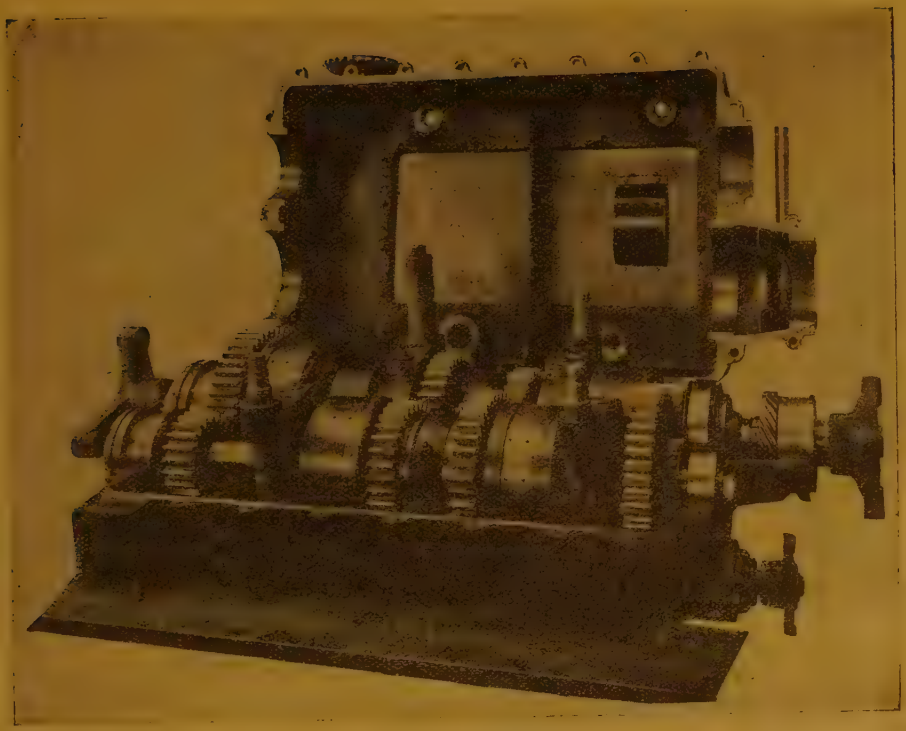


Fig. 28. — Ganz gear box.

Fig. 29. — Maybach gear box, 210 H.P.

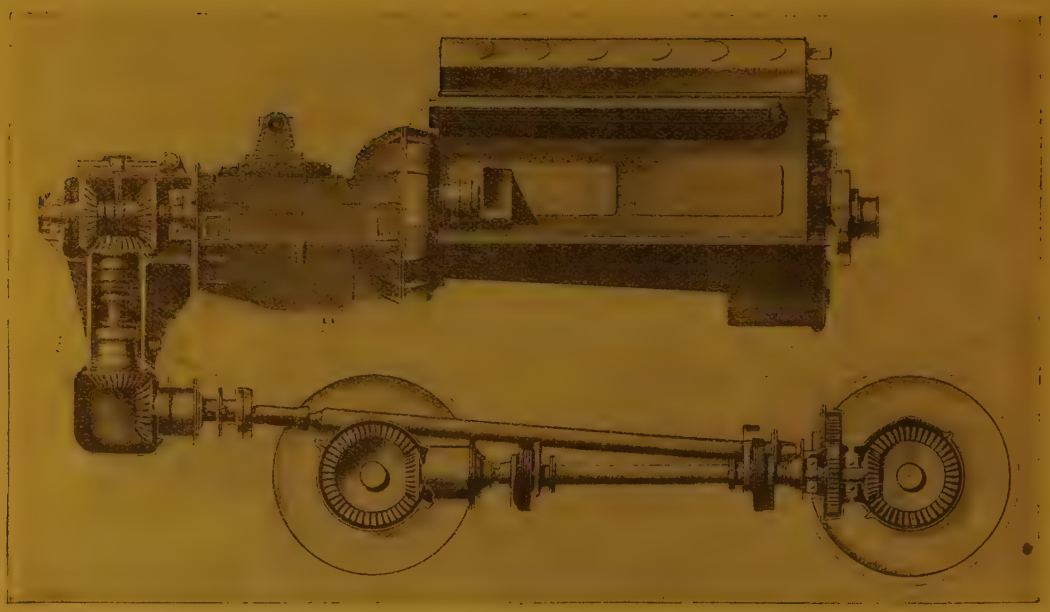


Fig. 30. — RENAULT transmission, 220 H. P.

The reverse is with bevels.

The total weight of a 210-H.P. Maybach transmission at 1 400 r.p.m. is 2 300 kgr. (5 070 lb.).

This firm has delivered 103 boxes for 150 to 210 H.P., and has 20 boxes in hand for the same range of powers.

g) *Minerva transmission.*

The speed gear box of this transmission has five gears, the first sliding and the others constantly in mesh. Mechanichal control is fitted.

The reserve gear has intermediate pinions.

h) *Renault transmission gear* (fig. 30).

The RENAULT gear box is a four-speed constant-mesh box, the speeds being selected by two dogs mechanically controlled.

Reversing is through bevel wheels.

The Renault gear box can transmit 250 H.P. at 1 500 r.p.m. and weighs 360 kgr. (793 lb.). The reverse gear, free wheel and motion with bevel gear wheels weigh 560 kgr. (1 234 lb.).

Forty 250-H.P. Renault transmissions have now been supplied and 80 are under construction.

i) *T.A.G. transmission gear.*

The T.A.G. gear box (fig. 31) gives four speeds in each direction. The gears corresponding to each speed are locked to their shaft by individual friction clutches pneumatically operated.

The total weight of the T.A.G. gear for 250 H.P. at 1 500 r.p.m. is 1 600 kgr. (3 527 lb.).

The T.A.G. Company has supplied 400 gear boxes, and has 43 in hand.

3. Transmissions with epicyclic-gear boxes.

a) *Baudet, Donon, Roussel transmission with Cotal electromagnetic gear box.*

The transmission gear on the railcars

Fig. 31. — T.A.G. gear box.

built by Messrs. Baudet, Donon, Roussel for the Paris-Lyons and Mediterranean, Paris-Orleans, and Nord Railways incorporate the following parts :

multiplate clutch of the dry-plate type,
cardan shaft,
reverse gear,
gear box,
speed reduction gear,
chain drive to the driving axle.

The bevel wheel type reverse gear is electromagnetically operated.

The Cotal gear box has two shafts, the primary and the secondary, placed in line with one another at right angles to the longitudinal centre line of the vehicle (fig. 32).

Each shaft carries a train of epicyclic gears with multiple planet wheels in constant mesh.

In the first train, the central pinion is keyed to the primary shaft. The internal toothed ring mounted loose on this shaft can be locked to it by exciting

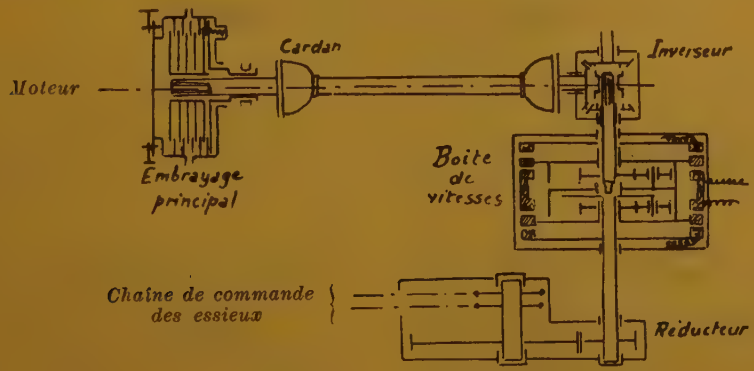


Fig. 32. — Cotal gear box.

Note. Chaine de commande des essieux = Axle driving chain. — Réducteur = Reduction gear.

one or other of the electromagnets surrounding it.

The plate carrying the planet wheels, in the second train, is rigidly fastened to the secondary shaft; the central pinion free to revolve on this shaft carries a plate which can be held locked by one of the electromagnets round it.

The plate carrying the planet wheels of the first train and the internal toothed ring of the second train form a single unit free to turn on the line of the shafts.

There are four electromagnetic clutches giving four speeds.

On direct drive, the two epicyclic trains form a block and the gears turn as a whole without relative movements. In the event of the current failing, the first speed can be locked mechanically.

A reduction gear (two Citroen chevron gears) is fitted behind the gear box. The secondary shaft of this gear carries two sprockets for a double roller chain which in turn drives two sprockets on the driving axle.

The COTAL box, without the reverse gear and the casing weighs 230 kgr. (507 lb.) and transmits 135 H.P. at 1 700 r.p.m. The firm has already supplied 19 boxes for 100 to 135 H.P. and has 4 more boxes for the same range of powers under construction.

b) *Wilson gear box.*

This box contains a number of trains of epicyclic gears (fig. 33). The desired speed is obtained by locking the rim of the corresponding train of gears by balanced brakes. These brakes are operated mechanically. The desired gear

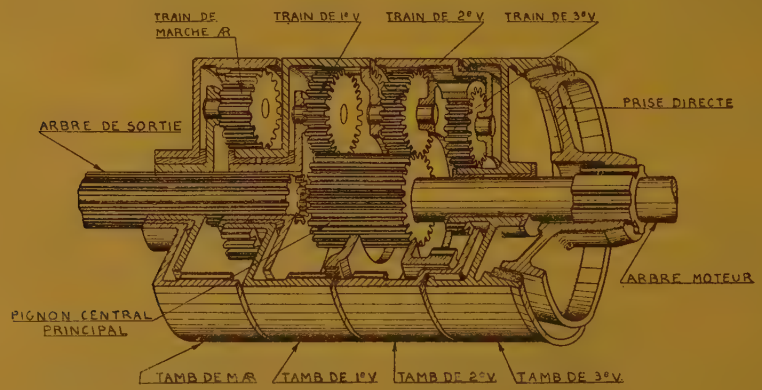


Fig. 33. — WILSON gear box.

Explanation of French terms:

Train de marche AR = Reverse running gear. — Train de 1° v (2° v, ... 3° v) = First (2nd..., 3rd...) speed gear. — Arbre de sortie = Driven shaft. — Prise directe = Direct drive. — Pignon central principal = Central main pinion. — Arbre moteur = Main shaft. — Tamb de M AR = Reverse gear drum. — Tamb de 1° v (... 2° v, ... 3° v) = First (2nd..., 3rd...) speed drum.

ratio can be preselected and is brought into use by pressing down the clutch pedal.

The fourth speed is the direct drive, when the whole of the gears revolves as a unit without relative movement of the parts.

The Wilson box is fitted on the 120-H.P. railcars built by the BREDA Company for the Italian State Railways.

4. Transmissions using a gear box with sliding gears.

When a sliding-gear box is used, the

same parts are included in the transmission as in those dealt with above :

clutch,
gear box,
reverse,
cardan shaft, and sometimes differential.

The railcars built by the Compagnie Générale de Construction de Saint-Denis, for the Paris-Lyons and Mediterranean Railways, are fitted with multiplate clutches of the dry-plate type. A clutch brake brings to rest the driven member when declutching and is controlled by the clutch pedal when the latter has travelled 4/5ths of its stroke.

The mechanically-operated gear box has three sliding gear wheels giving four speeds forward and one reverse.

Bevel gears are used for the reverse gear.

In the case of the Paris-Lyons and Mediterranean railcar built by Messrs. Delaunay-Belleville, the dry-plate clutch is followed by the reverse gear of the ordinary lay shaft type; four speeds can be obtained.

5. Various transmissions.

a) *S.O.M.U.A. transmission.*

The S.O.M.U.A. six-wheeled articulated reversible railcars of the French State Railways are fitted with a 210-h.p. diesel engine at 1 400 r.p.m.

The drive includes :

a Fieux type clutch,
a non-slipping clutch coupling with Belleville washer,
sliding gear box,
free wheel,
reverse gear,
two driving shafts each driving its axle through bevels.

Fieux clutch (fig. 34).

This clutch combines two distinct fittings.

The first, the « conjunctor » is a slipping device with large surfaces; the friction takes place between the inside surface of a cylindrical drum fastened to the diven shaft, and a coiled spring driven by the engine. This coiled spring is subjected to the differential action of centrifugal masses tending to press it onto the face of the drum, against the torque of the engine acting in the opposite direction. The fitting works in oil and is automatic. When starting the engine, power is transmitted with some slip until the engine speed becomes steady at a low speed corresponding to maximum power. When the vehicle speed corresponds to this speed, the two parts come together and the engine can be accelerated up to its normal speed.

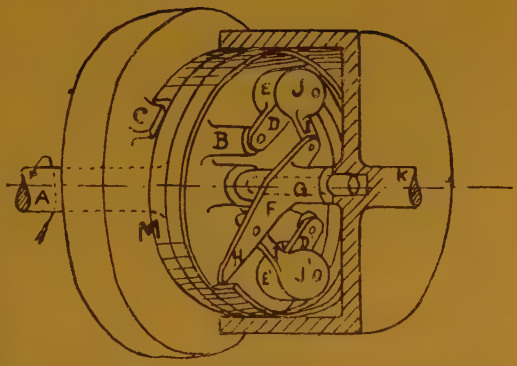


Fig. 34. — Fieux « conjunctor ».

The other fitting, the coupler, is a friction clutch with heavily loaded faces so that the driven member has little inertia. It is not required to slip and is operated just as an ordinary clutch.

As a result of this double equipment, we have :

Easy change of gear owing to the small inertia of the coupler, no great skill being required. Any slipping occurs automatically in the first fitting (the « conjunctor »).

Loss of engine speed through overloading or mishandling the gears is

limited to a certain value at which the two fittings separate.

The slipping device is designed to stand several minutes' slip under full load. The heat taken away by the oil is dissipated through the casing of the revolving part.

The Fieux clutch has made it possible to use the ordinary gearing with sliding gears or dogs on engines of 200-H.P. or over.

Free wheel (fig. 35).

A spring R fastened to the gear box secondary shaft E winds up on a nut B. When the shaft E revolves more quickly than the shaft F, the spring tightens up on the nut B and drives it at its own speed. The nut B then forces part A forward by sliding on splines which prevent it turning relatively to D. The dogs on A and C come together and F is driven by E. If E revolves more quickly than F, the reverse occurs. A pneumatic lock is provided to lock the free wheel in the driving position.

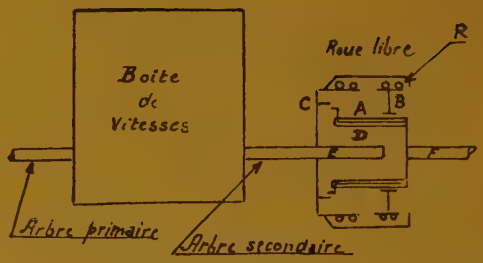


Fig. 35. — Free wheel.

Note: Roue libre = Free wheel.

b) *Bugatti drive without gear box.*

The BUGATTI drive is used on the high-speed railcar of the French State Railways (fig. 36) and on those ordered by the Alsace-Lorraine and Paris-Lyons and Mediterranean Railways.

Its main feature is that there is no gear box.

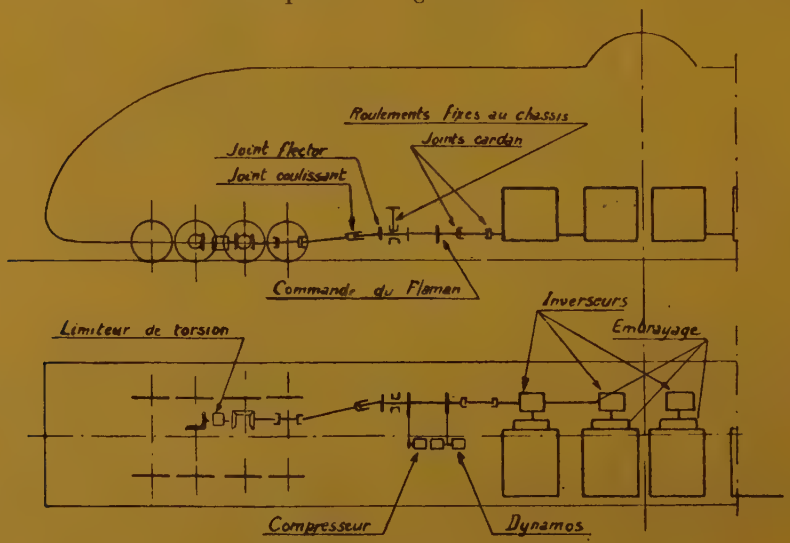


Fig. 36. — BUGATTI railcar. Diagram of mechanical transmission.

Explanation of French terms:

Roulements fixes... = Fixed roller bearings on frame. — Joint flector = Flector joint. — Joint coulissant = Sliding joint. — Joints cardan = Universal joints. — Commande du Flaman = Drive of Flaman recorder. — Limiteur de torsion = Torque limiter. — Inverseurs = Reverse gear. — Embrayage = Clutch. — Compresseur = Compressor.

The railcar has four 200-H.P. engines arranged transversely. Each engine has an oil-hydraulic clutch followed by a reverse gear (fig. 37).

Clutch. — The hydraulic clutch of the DAIMLER type, has two plates *a* and *b*, each with 24 radial vanes *c* and *c'*. One of these plates is driven by the engine,

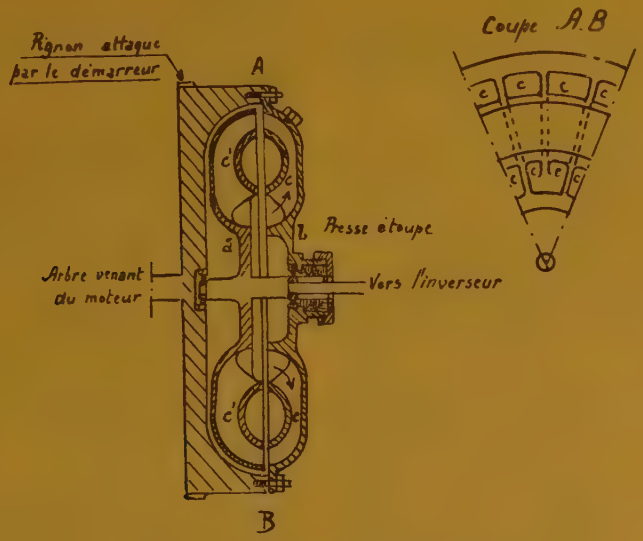


Fig. 37. — DAIMLER hydraulic clutch.

Explanation of French terms:
Pignon attaqué par le démarreur = Pinion driven by starter. — Coupe A.B. = Section A.B. — Presse-étoupe = Stuffing box. — Arbre venant du moteur = Main shaft. — Vers l'inverseur = To reverse gear.

the other is secured to the shaft and the reverse.

When starting, the liquid is set in motion by the moving plate *b*, circulates through the cavities *c* as shown by the arrows, and acting on the upper part of the vanes *c'* of the plate *a*, tends to drive this latter.

Some slip, about 1 % in normal working, has to take place between the two plates if the clutch is to transmit the engine power.

The pressure difference in the cavities *c* and *c'*, due to the difference in speed of rotation, ensures that the liquid flows in the direction indicated by the arrow.

Bevel gears are used for the reverse.

Line of shafts. — The rest of the gear consists of a line of shafts from each pair of engines to the corresponding bogie.

This line of shafts is supported by an intermediate roller bearing on the coach frame, and is fitted with flexible joints, both sliding and universal. It passes through an opening formed in the inner axle of the bogie (which is fixed as on a road motor car) and drives through bevels the two driving axles between which there is a torque limiting device.

Each engine can be run independently so that the coach can be driven by one, two, three or four engines.

* * *

PART III.

DISTANT CONTROL ON RAILCARS WITH MECHANICAL TRANSMISSION.

The injection pumps of the diesel engine, the gear box, the reverse or the clutch on railcars, are distant-controlled :

A. — mechanically,
B. — pneumatically,
C. — electro-pneumatically, or
D. — electrically.

A. — Mechanical control.

When mechanical control is fitted, the parts to be operated are connected to levers or pedals through rodding or metal cables.

In the case of four-wheeled railcars, or railcars with the engines in the car body, there is no difficulty in arranging this control, even when there are two driving compartments. In this case the controls are interlocked and cannot be misused, as the driver takes the driving handle with him when leaving the driving compartment.

When mechanical control has to be fitted to a bogie railcar with diesel engines on the bogies, a special layout is necessary, owing to the relative movement of the bogies. An example of this control is found in the Decauville railcar of the French Nord Railway.

This two-bogie railcar is fitted with Winterthur gear boxes. The engines are controlled by a pedal which operates the rack of the injection pump through rods.

When transmitting the motion from the body to the bogie the longitudinal movement of the rods is turned into rotary mouvement about their centre line. This rotary movement is then transmitted to the bogie through a cardan shaft with two universal, and one sliding, joints.

The same lever operates the rack controlling the injection pump on the opposite bogie. The rodding works in tension so as to avoid any whipping.

Very little movement is required to operate the distribution valves of the Winterthur gear boxes but great precision is needed. The control through levers or rods therefore operates a helicoidal gear which transmits its movement by a cardan shaft, two universal joints, and a sliding joint to the valves as in the control of the injection pump.

With this control gear, all parts are rigidly connected and the driver cannot cut out an engine if he wants to. If he has to, he must stop and first of all put the reverse gear into neutral, which can only be done under special circumstances on account of the work involved.

In addition to mechanical control by rods, metal cables are also used. The 175-H.P. Maybach railcars of the Belgian National Railways are controlled by steel cables. The reverse, fuel pump, and gear box are each controlled by an endless cable connecting the control drum to the wheel keyed to the fitting to be operated. The cables are guided by pulleys.

To get accuracy of movement, the cables are replaced by chains at the fittings.

Springs and tensioning devices are fitted to keep the cables in tension and to take up bogie movement.

The de Dietrich Company also used steel cables on the railcars it built for the Alsace-Lorraine Railways.

On this type of railcar, the 2 Mylius gear boxes are controlled by an endless cable which operates the gear lever of each box. This synchronises the different operations.

The clutches have each a compressed air servo-motor fed by the same feed valve distant-controlled by a steel cable from the control pedal.

Besides the cable controls, we must mention the CORSET A. D. N. system used

on the Paris-Orleans railcars built by the Aciéries du Nord de la France.

The CORSET transmission consists of a slightly flexible metal tube in which is threaded a string of beads formed alternatively of small barrels and small ovoids in hardened steel shrunk on a steel cable. This string of beads slides freely but without play in the metal tube.

Through the tension in the inside cable and the jamming of the barrels and ovoids a longitudinal movement in both directions can be transmitted at any point on the string of beads.

Each driving compartment is fitted with an arrangement which turns a sprocket wheel which gears with the string of beads, the displacement of which is communicated, at a suitable point along the tube and by a similar engagement, to another sprocket wheel which operates the equipment being controlled.

These devices show that railcar builders have been able to design a satisfactory distant control for operating the different fittings, even when the vehicle has two driving compartments and two driving bogies, with the engines on the bogie.

These controls are positive and safe. It must be noted, however, that mechanical control means a well trained staff as well as considerable effort, generally out of proportion to the work done. Multiple-unit working is out of the question when mechanical control is fitted.

B. — Pneumatic control.

When pneumatic distant control is used, compressed air servo-motors consisting of a cylinder with a piston working therein operate the different parts.

The compressed air is admitted to one or other face of the piston by a distributor valve which in some cases regulates the pressure. The piston movement controls the operation of the fitting concerned.

This servo-motor has been used with different gear boxes as we shall see in the descriptions below.

Distant control of the Fiat, Breda, and Somua six-wheeled railcars (fig. 38).

These railcars are all fitted with pneumatic distant control.

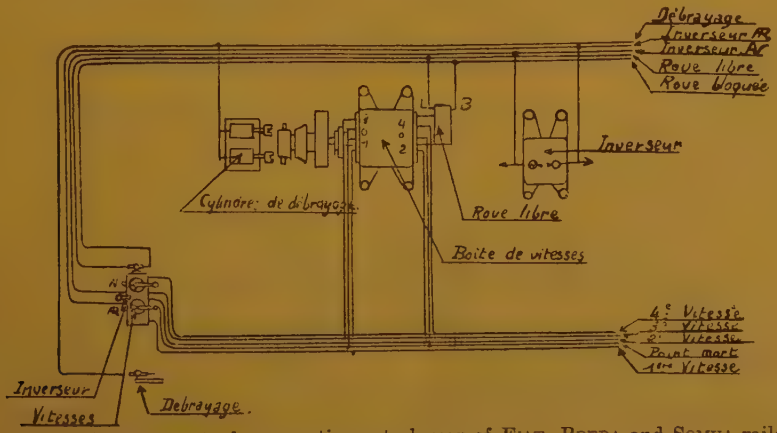


Fig. 38. — Arrangement of pneumatic control gear of FIAT, BREDA and SOMUA railcars

Explanation of French terms:

Débrayage = Declutching. — Inverseur AR = Reverse running. — Inverseur AV = Running forward. — Cylindres de débrayage = Declutching cylinders. — Roue libre = Free wheel. — Roue bloquée = Wheel driven. — Boîte de vitesse = Gear box. — 4e (3e.., 2e.., 1re...) vitesse = 4th (3rd.., 2nd.., 1st...) speed. — Point mort = Neutral point.

Speed gear control. — The gear boxes have as many compressed-air servo-motors as there are speeds. The servo-motors are connected by a two-valve distributor giving the following combinations:

1st valve	position 0 :	neutral,
	position 1 :	1st speed,
	position 2 :	2nd speed;
2nd valve	position 0 :	neutral,
	position 3 :	3rd speed,
	position 4 :	4th speed.

The zero position of the valves is central, so that to go from speed 1 to speed 2 it is necessary to go to neutral, which releases the gear in engagement. The two valves are mechanically interlocked to prevent any wrong movement. The driver has a check of the actual position of the gear by lamps which are either alight or out.

The reverse gear has two air cylinders, the pistons operating the fork moving the dog. These air cylinders are controlled by a three-position valve, the centre position opening the cylinders to the atmosphere. This valve is mechanically interlocked with the two gear box control valves so that the car cannot be reversed when a gear is engaged. The position of the reverse gear is repeated by a witness lamp supplied with current by a switch in the reverse gear box.

The clutch is controlled, like the reverse gear, by two air cylinders. Before changing gear it is, of course, necessary to declutch.

The injection pumps and the governor are controlled by an air cylinder. This cylinder is fed through a hand-operated pressure-reducing valve by means of rods and levers. The driver regulates at will the air pressure in the cylinder and so controls the stroke of the piston.

Figure 39 shows the arrangement of this control.

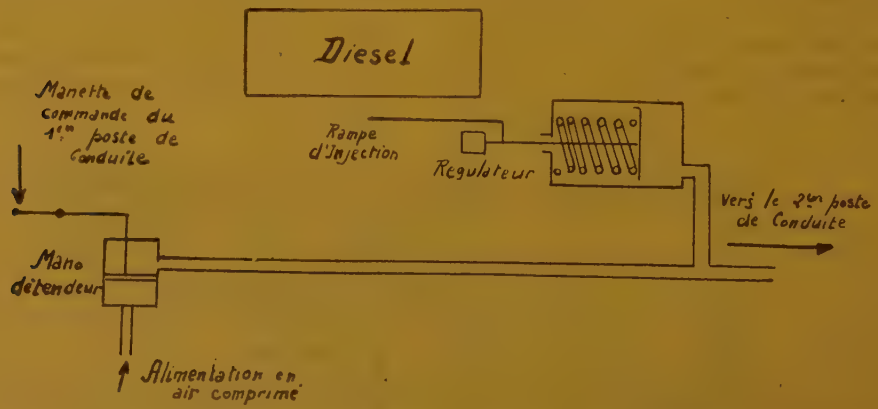


Fig. 39. — Layout of pneumatic fuel injection control on FIAT, BREDA and SOMUA railcars.

Explanation of French terms:

Manette de contrôle du 1er poste... = Control handle of first driving compartment. — Rampe d'injection = Injection pipe. — Régulateur = Governor. — Vers le 2e poste de conduite = To 2nd driving stand. — Mano-détendeur = Pressure reducing valve. — Alimentation en air comprimé = Compressed air supply.

The railcar having two driving compartments, in each of them there is a valve for shutting off the controls. In addition the reverse gear handle, when put into the neutral position, can be removed and this locks the gear box and clutch control.

The two compartments are connected together by pipe lines on the frame.

Control of injection pumps on the Aciéries du Nord railcar for the Paris-Orleans Railway.

This railcar has mechanical drive and is designed to run at a relatively constant speed, no matter what the gradients of the line may be.

The governor control is based on there being equilibrium between the axial thrust of a mass rotating at the same speed as the engine and that of the piston on which compressed air acts after its pressure has been dropped by the driver by means of a regulating cock. At each of its displacements, the piston acts itself on the injection pump rack.

Control of the clutch and fuel pumps. Baudet, Donon, Roussel system, on the reversible twin railcars of the Paris-Lyons and Mediterranean, Paris-Orleans, and French Est Railways.

The control is pneumatic. It consists of a compressed-air servo-motor acting on the fork operating the sliding clutch plate.

The progressive movement of this sliding clutch plate is governed by a pedal-controlled valve. When the pedal is pushed down compressed air is allowed to escape from the main reservoir at a pressure proportional to the force exerted by the pedal. The piston thus exerts on the fork a force proportional to that exerted by the driver. The pedal is interlocked with the change speed gear selector and makes it necessary to declutch when changing gear. It is also connected pneumatically to a valve which applies the brake, should the pedal be let go, thereby providing the safety device known as the dead man's handle.

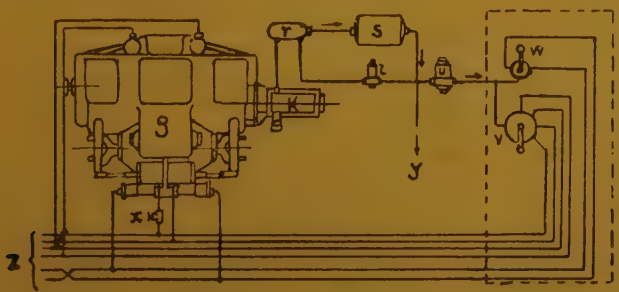
The fuel pumps are also pneumatically operated. A pressure reducing valve controlled from each driving compartment by lever and rods feeds air from the main reservoir at a pressure proportional to the movement of the said lever, to a servo-motor with a cylinder and a series of concentric pistons of different diameters, the stroke of each being limited by adjusting nuts. These pistons transmit their movement to a control spindle coupled to the fuel pump. This spindle is spring-loaded.

This equipment provides the control for a railcar with an engine on each bogie, or two railcar units coupled together, whilst the driver can use one or other engine at will.

When two railcar units are coupled together, the valves on the leading car feed the clutch and pump servo-motors on the second car under the same conditions. The valves on the second car are cut out, at the same time as those of the direct acting brake and the main reservoirs, by a lever on the frame.

Distant control of the T.A.G. gear box (fig. 40).

The constant-mesh T.A.G. gear box



g = Gear box.
k = Compressor.
r = By-pass reservoir.
s = Main reservoir.
t = Adjustment of pressure.
u = Pressure reducing valve.
v = Four-way cock.
w = Reversing cock.
x = Adjusting valve for smooth throwing into gear.
y = To compressor.
z = To 2nd driving compartment

Fig. 40. — Control of T.A.G. gear box.

has a friction clutch for each train of gears. The movable part of each clutch is operated by a compressed air servo-motor, built into the gear box, the servo-motor consisting of a cylinder and a piston acting on the clutch through a lever.

These servo-motors are pneumatically controlled on railcars running as separate units or hauling very small rakes of stock. In this case, each driving compartment is fitted with a four-way valve distributing compressed air to the servo-motors. The valve is connected to the servo-motor by piping on the coach.

The reverse gear in this box also includes two compressed-air servo-motors controlled by a valve. The diagram shows the layout of this distant control. The compressed air is supplied by a compressor automatically controlled with a maximum pressure valve as well as a light running valve when the maximum pressure has been reached.

The first speed gear cylinder is fitted with a valve controlling the compressed air supply, so as to get a very gentle start. This valve can be set as required, and when changing from 1st to 2nd speed it also allows the air to be exhausted straight to the atmosphere, without passing through the valve in the driving compartment. This arrangement makes it possible to effect a quicker change of gear.

C. — Electro-pneumatic controls.

Electro-pneumatic controls have been developed from the pneumatic controls and the compressed air servo-motors are based on the same principle. The air is admitted to the cylinders through electro-valves through which current from a battery of accumulators flows.

The electro-pneumatic control lends itself very well to the different combinations to be made and is very useful when the railcar has to haul a trailer or when two railcars are coupled together.

The electrical action is so rapid that there is perfect synchronisation when changing gear.

Jourdain-Monneret electro-pneumatic distant control fitted to the Delaunay-Belleville railcars of the Paris-Lyons and Mediterranean Railway, and the two Renault railcars of the French State Railways.

With this equipment the distant control of the change speed gear, the reverse gear, the clutch, and fuel pumps of a twin reversible railcar with one or more engines is possible. Only the pumps are pneumatically controlled, and not electro-pneumatically.

The compressed air servo-motors of the different controls are fed by a set of electro-pneumatic valves worked by a controller with two drums. The first operates the change speed gears, with stop and intermediate positions, and the second controls the forward and reverse running.

The speed drum is operated by a handle hinged in the vertical plane and normally held upwards by a spring. The handle can occupy four positions corresponding to the excitation of each of the electro-valves of the speed gears, with a series of notches which have to be passed to get into the next higher or lower gear, the clutch being released after the desired gear has been selected.

This mechanical use of notches prevents the driver gearing up too quickly, just as it stops him gearing down at too rapid a rate.

Provision is made for declutching instantaneously in case of danger, and for preventing the driver from restarting in the gear in which he was when he stopped.

The injection pumps of the Diesel engine are controlled by a handle on the master controller operating a special valve which sends compressed air into a servo-motor with a piston counterbalanced by a tared spring. This piston moves

proportionately to the angular displacements of the valve handle and controls the fuel pump.

When running with several engines or in multiple units the electro-control valves are fitted in parallel and an equipment can be cut out by opening the switches on the return circuits of the electro-valves.

A.E.G. electro-pneumatic control (fig. 41).

The A.E.G. electro-pneumatic control differs from the Jourdain-Monneret by

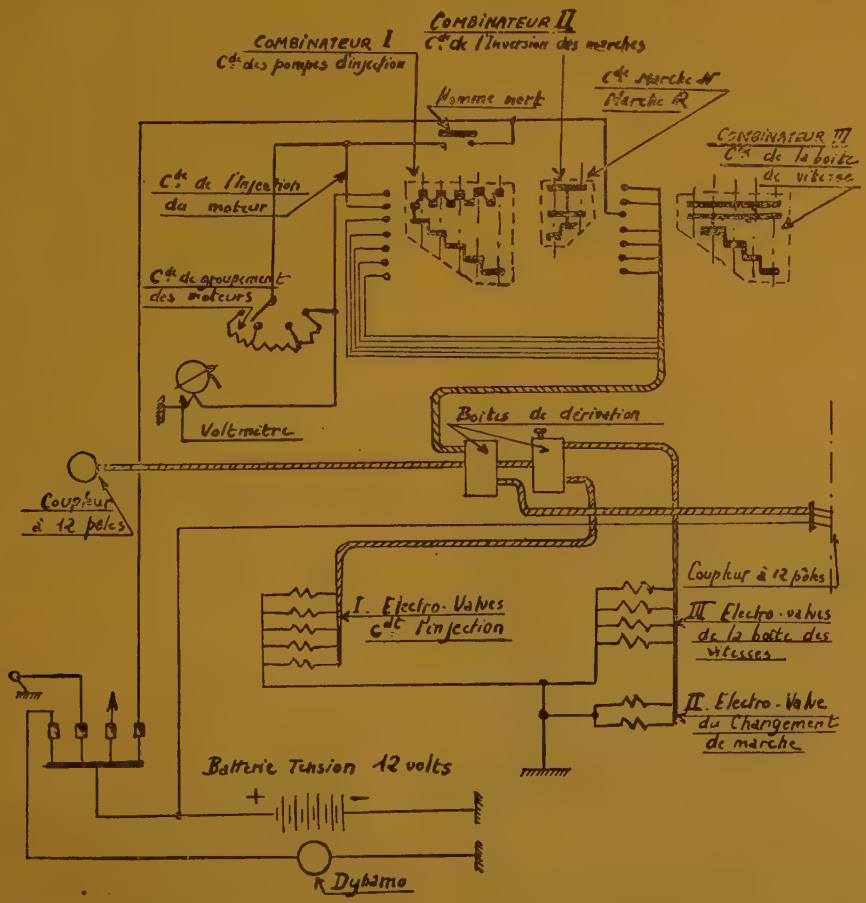


Fig. 41. — Layout of electric control of a railcar with mechanical drive (A.E.G. system).

Explanation of French terms:

Combinateur I (... II..., III) = Switchbox I (... II..., III). — C^{de} des pompes d'injection = Control of injection pumps. — C^{de} de l'inversion des marches = Control of forward and reverse running. — Marche AV = Foregear. — Marche AR = Reverse running. — Commande de l'injection du moteur = Fuel injection control. — C^{de} de groupement des moteurs = Control of engine grouping. — Boîtes de dérivation = Junction boxes. — Coupleur à 12 pôles = 12-pole circuit closer. — Electro-valves c^{de} l'injection = Electro-valves controlling the injection. — Electro-valves de la boîte de vitesse = Electro-valves of gear box. — Electro-valves du changement de marche = Electro-valves of reverse gear.

the control of the fuel injection pumps of the Diesel engine, which in this case includes five electro-valves, acting on the governor.

The diagram shows the layout of the equipment.

The driver can use as many engines as is necessary, by a grouping rheostat.

Messrs. Baudet, Donon, Roussel have improved the electro-pneumatic distant control of the reverse gear on their cars.

In this arrangement the electro-valves are fed separately or together and consequently forward, backward, or neutral positions can be obtained.

The fork operating the dog is fitted with a rocker operating switches which shut off the current from the electro-valves as soon as the dog is engaged.

D. — Electric control.

Electric control has been little used up to the present. There is one particular application, however, to the control of the Cotal gear box which is electro-magnetic. The gear is changed by two selectors (one in each driving compartment) on the same support as the drum controlling the change speed gears and setting up the combinations corresponding to the four speeds in the box.

Moreover, by a mutual interlock, the speed control drum can only effect the four changes when the reverse gear is in forward running. In back gear, the speed gear drum can only give the first speed and is locked in the neutral position when the reverse gear is in the « stop » position.

Further, the speed drum can only be operated when the driver presses down the declutching pedal.

Distant-operated electric controls have also been used to work the governors of Diesel engines in some electrical drives with a limited number of running positions (Oerlikon drive, for example, of the Compagnie Française de Matériel de Chemins de fer). These gears embody electro-magnets with plungers acting directly on the governor springs.

* * *

Generally speaking, it seems that on recent railcars pneumatic or electro-pneumatic control gear are given the preference when the engines are mounted on the bogies, or the cars are to be run as multiple units.

Pneumatic control is particularly advantageous in the case of mechanical transmission for controlling the fuel pumps. It allows of all speeds from the slowest to full power being obtained, as it acts progressively on the engine governors, whereas when electro-pneumatic control is used it is necessary to proceed in steps.

The reverse gear can be distant-operated satisfactorily by electro-pneumatic gear, though this is rather costly; however, it gives all the combinations and interlockings required when operating a railcar with one or several engines.

* * *

CHAPTER IV.

ELECTRIC TRANSMISSIONS.

The essential feature of an electric transmission is a direct-current generator, coupled to the heat engine, and supplying current to the series type electric traction motors.

The following are the variables of the electric transmission problem :

1. Degree of admission of the fuel,

which determines the power of the heat engine.

2. The excitation of the generator.
3. The speed of the diesel engine.
4. The speed of the vehicle.

These four variables are interdependent. If two of these variables are known, the law of variation of the two others can be defined. In practice, the injection of the diesel and the excitation of the generator are fixed.

Indeed, for a given injection, the torque of the diesel engine is known. In the same way, when the excitation is settled, the torque of the generator depends on the speed of the vehicle alone. We can, in fact, knowing the characteristics of the traction motors, determine for each speed of rotation of the generator, the resisting torques c_1, c_2, c_3, and c_4 of the latter at the different vehicle speeds V_1, V_2, V_3 and V_4.

These torques are given by the intersection of the characteristic line of the generator at the speed N_1 with the curves V_1, V_2, V_3 and V_4, which give the voltage in terms of the current intensity for each rotational speed V_1, V_2, V_3 and V_4 of the traction motor (series motor) and consequently of the vehicle speed (fig. 42).

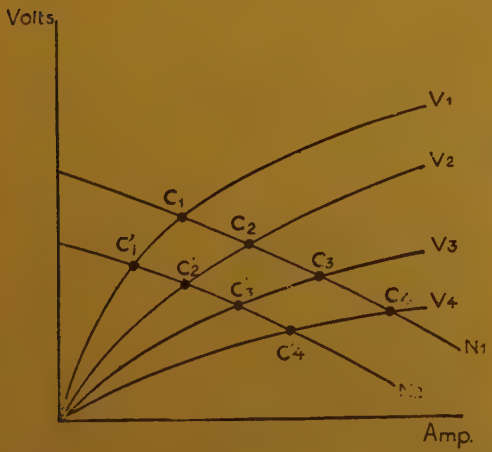
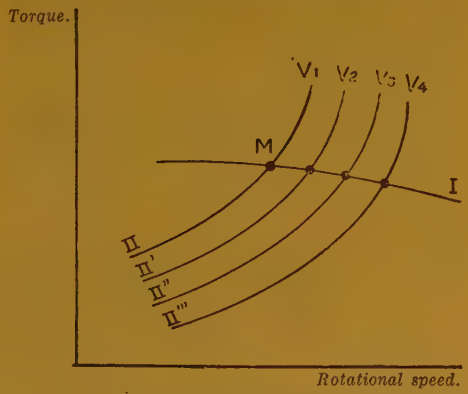


Fig. 42.

Knowing these torques, the law of variation of the resisting torque of the generator in terms of its speed of rotation and for each vehicle speed (fig. 43) can be calculated.



I = Torque of diesel engine.
II, II', II", II"' = Torque of electric generator at speeds V_1, V_2, V_3, V_4.

Fig. 43.

As the torque of the diesel is fixed, as we have said above, by the injection of fuel, and as all steady running of the diesel generator set implies equal torque of the diesel and of the generator, the intersection M of the curves, representing them in terms of the speed, defines the said speeds of rotation of the diesel-generator unit, and consequently gives the law of variation of the speed of the diesel engine in terms of the speed of the vehicle.

Fig. 44.

The problem, it will be seen, is quite different from that of electric traction, in which the voltage on the contact line is constant. With diesel traction, the generator should adapt itself to the diesel engine and supply by itself current the voltage of which meets the needs of the traction motors.

The variables of the problem being known, for any particular railcar speed there will be a definite tractive effort, as well as a well-defined speed of the diesel engine, and inversely an electric transmission can always be calculated so that to each speed of the railcar corresponds a selected tractive effort, which may be the maximum tractive effort compatible with the adhesion, or the maximum tractive effort corresponding to the power of the engine.

The curve below, obtained with the Jeumont transmission, of the Aciéries du Nord railcar, shows that up to a speed of 18 km. (11.2 miles) an hour the start of the railcar is limited by the adhesion and that above 18 km. an hour, the transmission uses the whole available power of the diesel engine (fig. 45).

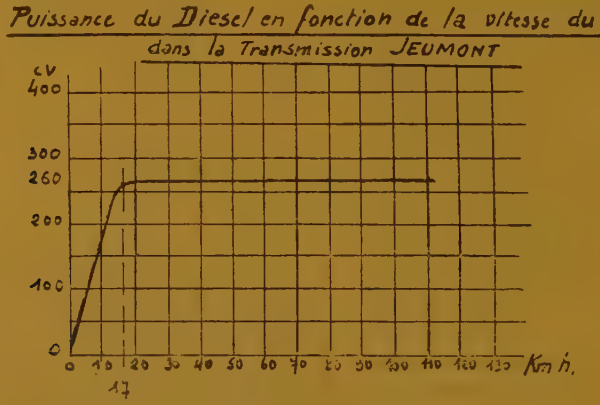


Fig. 45.

Note: Puissance du Diesel... = Power curve of Diesel engine in terms of the vehicle speed, with the Jeumont transmission.

In the case of diesel traction, it is of the utmost importance that the full power of the diesel engine should be adequately used. All builders of electric transmissions endeavour to follow as nearly as possible, at least in the last step of the controller, the equilateral hyperbola in which.

$$E\,I = \text{constant}.$$

This condition would be all that is required if it were possible to design an equipment which would invariably give $E\,I$ = constant. The variation of the torque of the generator in terms of its rotational speed would be a line, and the diesel engine would run at an exactly constant speed for a given fuel injection.

If the system does not give constant power, the variation of the generator resisting torque in terms of its speed is represented by a zone (fig. 46), and it will be appreciated that, owing to the slightly descending line of the diesel torque curve, in practice the diesel engine power can be made good use of by varying its speed. But then the generator should be so designed that these variations in speed of the diesel are such as will preserve the engine.

The builders have exercised their ingenuity, as we will see below, in keeping by force (in the case of the first kind

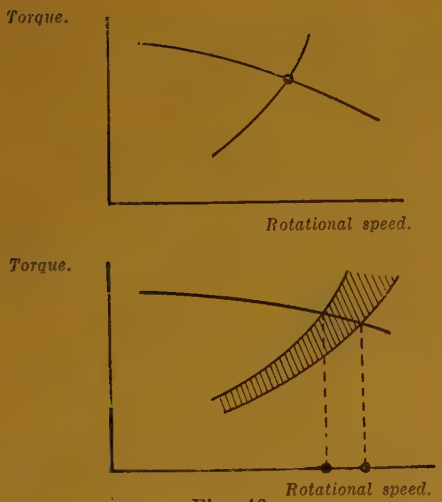


Fig. 46.

of transmission) or by good fortune (in the case on the second class of transmission) the voltage and current intensity to this hyperbola.

The hyperbola selected, moreover, is that for which the diesel engine is able to work indefinitely under economical conditions.

Another more important consideration, however, than that of the most economical output, has to be taken into account when selecting the method of excitation of the generator, as this determines the wear on the diesel engine, should it work at too high a torque at lower speeds than those intented.

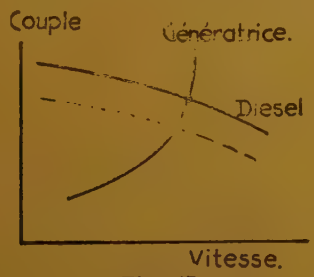


Fig. 47.

Note: Couple = torque. — Génératrice = generator. Vitesse = speed.

Generators have therefore been designed which, while giving practically constant powers in terms of the vehicle speed, are capable of great variations of resisting torque for slight speed variations of the diesel engine; these generators thereby prevent anything going wrong with the working of the diesel engine (choked injector, pump out of order, etc...) which might lead to a dangerous reduction in engine speed.

* * *

Electric transmissions can be classed under two groups which have been excellently defined by Mr. Hennig (*Bulletin of the International Railway Congress Association*, July 1935, in the following way :

A — transmission with exterior action on the generator field;

B — transmission with self-regulating generator.

The essential difference between these two groups of transmissions is that the characteristic curves of group A transmission dip slightly as (III) whereas those of group B dip quickly as (IV).

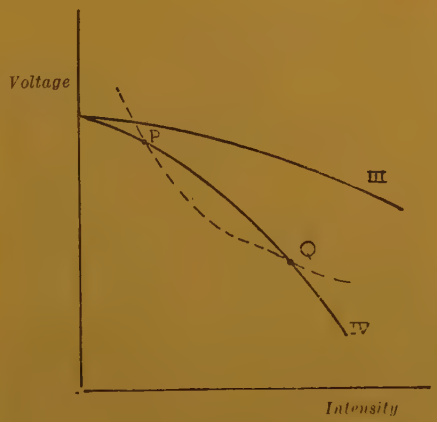


Fig. 48.

The characteristic curves (IV) therefore intersect at two points P and Q, the equilateral hyperbola, and the electric system will operate practically by itself between these two points.

Contrariwise, with the characteristic curve (III), it is not possible to follow the hyperbola, and exterior action on the field is essential to assure working at equal power.

In the case of group A transmissions, the action on the field is exercised either manually (non-automatic transmission such as Ward-Léonard. A. S. E. A. first type), or automatically as in the case of the following transmissions :

1. French Jeumont transmission (action by axle driven exciter);

2. Swedish A. S. E. A. transmission (action by regulator-motor controlled by the intensity of the traction current);

3. Brown-Boveri transmission (action of the diesel governor on the generator field).

In practically all group A transmissions, the speed of the diesel engine is constant for each controller step.

Group B transmissions, on the contrary, can only work if the diesel engine is free to adapt its speed to the requirements of the transmission; they are all derived more or less from the Gebus transmission, namely :

1. the Oerlikon transmission;

2. the Gebus transmission properly speaking;

3. the American Lemp transmission;

4. the standard R.Z.M transmission of the Reichsbahn;

5. the A. E. G. transmission.

A. — Systems with exterior action on the generator field.

1. The electric transmission of the Forges et Ateliers de Constructions Electriques de Jeumont (fig. 49).

In this design, the field windings of the generator G are fed by an exciter E running at a speed proportional to that of the traction motor M to which it is coupled mechanically. This exciter E is itself excited by a storage battery the current of which can be controlled by a rheostat Ra.

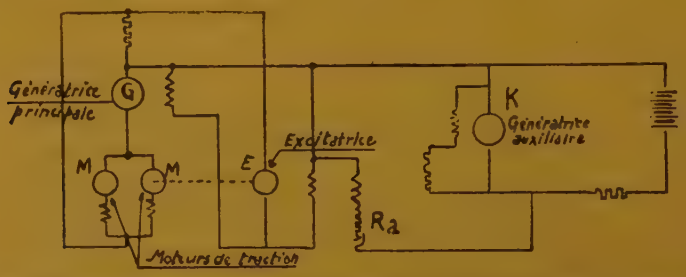


Fig. 49. — The JEUMONT transmission of the Aciéries du Nord railcar. — Principle of design.

It will be seen that when about to start, and the traction motor has not yet begun to revolve, if the generator has no residual excitation, the exciter cannot supply exciting current, as it is not in motion; the generator cannot produce any current and the vehicle cannot be started.

To overcome this difficulty, a battery can be inserted in the generator exciting circuit, to provide a certain amount of excitation even when the exciter is not

revolving. This battery can, moreover, be inserted in the traction motor circuit so as to be recharged automatically whilst the railcar is running, by current from the generator.

Besides, the battery can be replaced by a small ohmic resistance. The generator, at starting, would then be excited as though it were a series generator with the field magnets shunted by this resistance.

Once the vehicle has started, the working is controlled by the fuel admission valve and the exciting rheostat of the exciter.

In all cases, the intensity of the exciting current and the speed of the railcar automatically vary inversely for any given power corresponding to a given fuel admission, and for any given resistance of the exciter rheostat; the speed of the heat engine also varies but not below a certain rate depending on the setting of the excitation regulating resistance and, of course, the admission of fuel.

The advantage of this system is that the full engine power is used for wide variations in the working conditions of the motor coach.

The heat engine can also be run in the most economical way for each degree of admission, as the speed of the engine can always be brought to its optimum value by the field regulating resistance.

This system in an example of what can be done to get the best operating conditions, as regards both power and fuel economy. It is only obtained at the price of some complication, and batteries are necessary.

An example of a railcar designed on the above principles is the one supplied to the French Nord Railway by the Aciéries du Nord Company, with a 200-H.P. diesel engine and two traction motors. It is a 2-B_0 type coach.

Besides the equipment theoretically necessary, this railcar has an auxiliary generator K, driven by the diesel engine, which charges the batteries and also supplies current for one of the methods of exciting the axle-driven exciter which has a shunt winding and a special winding.

The diesel engine is controlled by electro-pneumatic valves whereby its speed can be limited. One of these valves is operated by the starter and corresponds to the slow running speed of the engine. The three others are part of the controller and correspond : the first two to constant speeds of 650 and 850 r.p.m., and the third to variable speeds between 900 and 1 200 r.p.m.

The theory we have developed above applies to this range of speeds of the internal combustion engine, as there is no fear of critical speeds being set up in this zone.

This zone corresponds to seven notches on the controller, that is to say seven adjustments of the power obtained by varying the excitation of the auxiliary generator and the separate excitation of the axle-driven exciter.

As regards using the power of the diesel engine in terms of the vehicle speed, the recorded curve (fig. 45) shows that, as soon as the speed reaches about 20 km. (12.4 miles) an hour, the full power of the engine is always available.

In the equipments for five triple railcars of the Belgian National Railways Company, the method of exciting the main generator has been slightly altered: the vehicle is started by an independent winding fed by the battery of accumulators.

Equipment of the 1935 type express railcars of the Nord Railway (France).

The Forges et Ateliers de Constructions électriques de Jeumont have designed a new electrical equipment for the 1935 type express railcars built for the Nord Railway.

The principle of this transmission is

the same as that dealt with above, i. e. an axle-driven exciter is used to keep the power developed by the diesel engine constant, whatever may be the vehicle speed.

The diesel engine drives a 260-kw. D. C. generator, the generating set being carried on one of the bogies. The generator supplies current to two nose-suspended series-excited traction motors, mounted on the other bogie.

The axle-driven exciter E, driven by a carrying axle to limit the skidding effect, is relayed by a relay-exciter ER driven from the diesel engine. This relay-exciter supplies the total excitation of the generator.

The relay-exciter works on the straight part of its characteristic and has four exciter windings (fig. 50).

1. A shunt winding (1) designed to

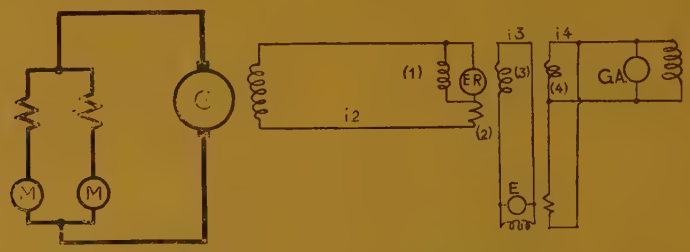


Fig. 50. — JEUMONT equipment for the 1935-type fast railcars. — Principle of design.

supply by itself all the ampere-turns needed for magnetisation, i.e. such that the straight line of the field magnets coincide with the characteristic curve of the machine.

2. A series de-magnetising winding (2).

3. An independent winding (3) through which flows the current i_3 from the axle-driven exciter.

4. An independent winding (4) through which flows the current i_4, supplied by the auxiliary generator GA.

The windings (3) and (4) are magnetising.

The machine is in equilibrium when the series ampere-turns and the sum of the ampere-turns of the two independent windings are equal.

Consequently the relay-exciter automatically supplies to the generator an exciting current $i_2 = a\ i_3 + b\ i_4$, whatever the resistance of the exciting winding of the generator. So that the excitation i_2 should not be affected in practice by the temperature, the windings (3) and (4) have been designed for small temperature rises, and resistances which do not vary with the temperature have been introduced in series.

This system makes it possible :

a) to govern the resisting torque of the generator which is a function of the speed of the train;

b) to obtain a resisting torque which is independent of the temperature of the windings;

c) to have a very wide variation of the resisting torque when the speed of the diesel varies for any reason.

2. A.S.E.A. transmission.

The A.S.E.A. automatic system (fig. 51) uses a main generator (1) the exciting current of which (winding *a*) supplied by an auxiliary constant-voltage exciting generator (2) is automatically governed by a regulating motor (3) inserted in

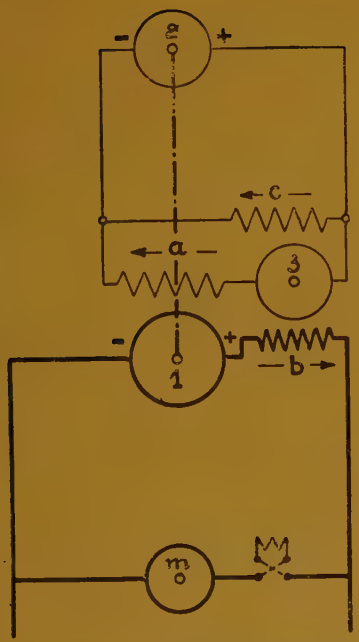


Fig. 51. — A.S.E.A. automatic transmission. — Principle of design.

the external circuit of the exciter. This regulating motor has two exciting windings : one (*b*) through which the main current flows, the other (*c*), in opposition, fed by the constant-voltage current of the exciter.

The difference between the constant-voltage of the exciter and the voltage of the regulating motor (counter-electromotive force varying with the amperage of the main current) sets up a flux in the main generator which changes very closely inversely as the strength of the main current.

This device is very simple and entirely automatic; it has been fitted to a railcar built by the Aciéries du Nord for the French Nord Railway.

3. Brown-Boveri transmission.

The Brown-Boveri transmissions employ :

a) either a generator with completely independent excitation in the automatic transmissions made by Brown-Boveri (Mannheim);

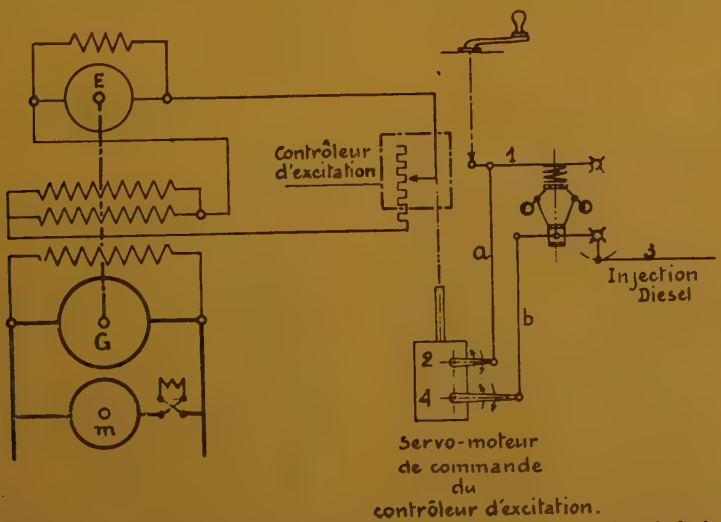


Fig. 52. — Brown-Boveri (Baden) transmission. — Principle of design.

Note : Contrôleur... = Excitation controller. — Servo-moteur... = Servo-motor controlling the excitation regulator.

b) or a generator with separate excitation and shunt self-excitation, as in Brown-Boveri's (Baden) automatic transmission.

In these systems the current for the separate excitation is still supplied by an auxiliary generator (exciter) coupled to the shaft of the main generator but the excitation is regulated, in this case, *automatically* by a field rheostat (drum type of excitation controller) inserted in the external circuit of the exciter and depending on the main current. This is achieved :

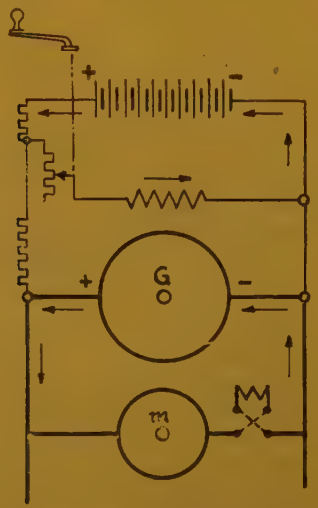
either by, in the Brown-Boveri (Mannheim) system, a power relay (wattmeter type) operating the drum of the excitation controller through a magnetic interlocking;

or, in the Brown-Boveri (Baden) system (fig. 52), by a device which couples together the drums of the exciter controller and the sleeve of the diesel governor through a slide-valve-operated oil-pressure servo-motor. With this arrangement, as soon as the intensity of the current taken by the traction motors varies in either direction, the corresponding variation of the generator load tends to upset the equilibrium of the diesel governor. The sleeve of the latter immediately acts on the injection of the diesel (through the rods 3) and on the drum of the excitation controller (through the rodding controlling the distribution valve (4) of the oil-pressure servo-motor).

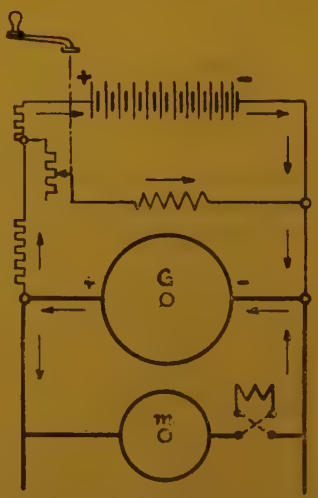
This twofold action immediately re-establishes the balance momentarily upset. Regulation of the torque of the generator, to obtain a desired working power, is obtained by acting on the excitation controller through the rodding (1) varying the tension of the governor spring.

This rodding is connected by a spindle *a* to the control of a cam shaft (2) regulating the action of the servo-motor on the excitation controller drum.

The B.B.C. transmission has been used on some of the 410-H.P. railcars of the Deutsche Reichsbahn.



Generator acting as separate excitation (starting).



Generator acting as shunt-wound self-excitation and for charging the battery (full speed).

Fig. 53. — Oerlikon transmission. — Principle of design.

B. — Transmissions with self-regulating generator.

1. Oerlikon transmission.

The Oerlikon Company have endeavoured to obtain, if not perfectly constant power absorbed by the generator, at least a great simplicity in order to reduce the electrical equipment to a minimum weight.

In principle the generator is a shunt-wound self-exciting one. In order to avoid the difficulties in starting the generator, however, the field winding of the latter is used during the starting of the railcar as a separate excitation winding fed by a battery of accumulators.

When the railcar has been started, the generator acts as a shunt-wound self-exciting generator, and recharges the battery.

A resistance controlled by a hand-operated rheostat is inserted in the excitation circuit in order to enable the driver to select a given working power.

This transmission is employed on a 130-H.P. railcar built by the « Compagnie Française de Chemins de fer » for the Paris-Lyons & Mediterranean Railway (France), and on two railcars by the same builder for the French Nord Railway.

2. The Gebus transmission (fig. 54).

This system, also very simple, uses like the Oerlikon system, a shunt-wound self-exciting generator. However, instead of using a battery of accumulators to facilitate starting up the generator, the Gebus Company has given the generator a series winding so designed that its field only affects the generator for heavy main-current intensities, that is to say when the railcar is started.

In addition, the Gebus generator only works in the non-saturated parts of its magnetisation curve, a region lying at the end of the most markedly inclined part of this curve and at the beginning of the bend connected to this part. Under these conditions, slight variations in the angular speed can produce sufficiently rapid voltage variations, so that each time the dynamic balance is disturbed, a new point of equilibrium at a slightly different speed is arrived at very soon.

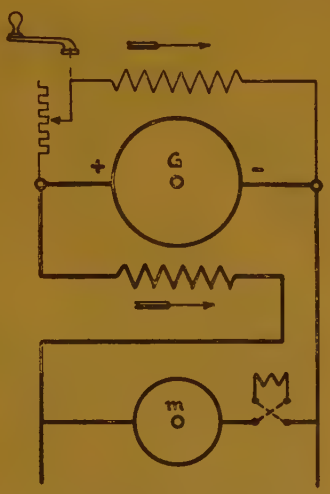


Fig. 54. — Gebus transmission. Principle of design.

A field rheostat acting on the adjustable resistances inserted in the shunt winding of the generator, the operating of which is linked up with the control, by the electric servo-motor, of the arrangement for adjusting the tension of the spring of the diesel centrifugal governor, enables the driver to select one of a number of ranges of working power.

The GEBUS equipment is fitted on the German State Railways' express double railcar (Schnelltriebwagen), of which figure 55 shows one of the driving cabins.

The 40 triple railcars (1934 type) of the Netherlands Railways, the double railcar of the Belgian National Railways, built by Messrs. La Brugeoise, and two express triple units of the French

Fig. 55. — Driving compartment of « Schnelltriebwagen ».

Nord Railway, are all fitted with a modified Gebus transmission, in which resistances are inserted in the shunt exciting circuit of the generator at the same time as the diesel engine governor is altered. The excitation of the generator is facilitated by a series field winding.

3. The American « Lemp » transmission of the A.E.G. (fig. 56).

The main generator (1) has two field windings A and B fed by an auxiliary generator (exciter) (2), excited by a battery of accumulators (3).

The main generator and the exciting generator are coupled to the diesel engine crank shaft.

One of the field windings (A) of the main generator is connected directly to the terminals of the generator. The other (B) connected in parallel on the winding A, is coupled to the terminals of the battery, which can in this way be charged by the exciter.

In addition, the exciter is decompounded by the main current which has the effect of accentuating the dipping form of the characteristic of the main generator.

Finally, thanks to this method of excitation, slight variations in angular speed are sufficient to induce sufficiently rapid variations of voltage at the terminals of the main generator, these variations

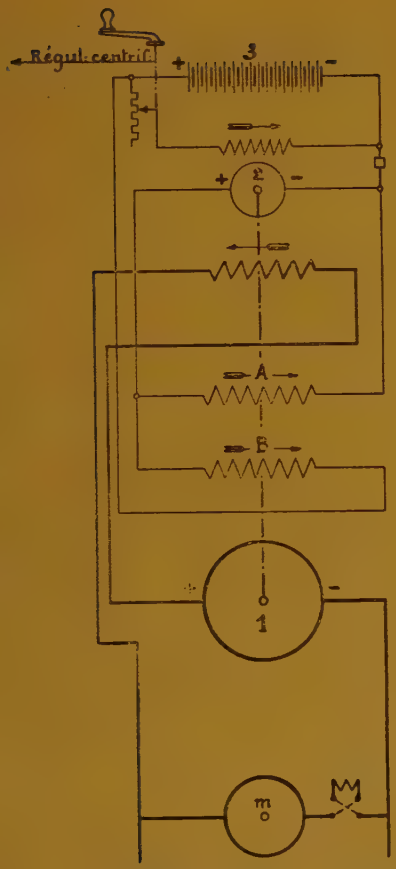


Fig. 56. — American « Lemp » transmission. Principle of design.

in speed reacting at the same time on the pressure of the exciter governing the field of the main generator and on the voltage of the latter.

As regards starting the railcar, this is assisted by bringing in the battery to excite the exciting generator.

4. Standard R.Z.M. transmission of the Reichsbahn (fig. 57).

Based on the American « Lemp » transmission and the « Gebus » transmission, the Reichsbahn has introduced a standard system the principle of which is the following :

The main generator (1) with combined anticompound excitation (fig. 57) has three windings, namely :

— a separate winding (*a*) fed by current from an auxiliary generator (exciter) (2) coupled to the generating set and acting as compound self-excitation;

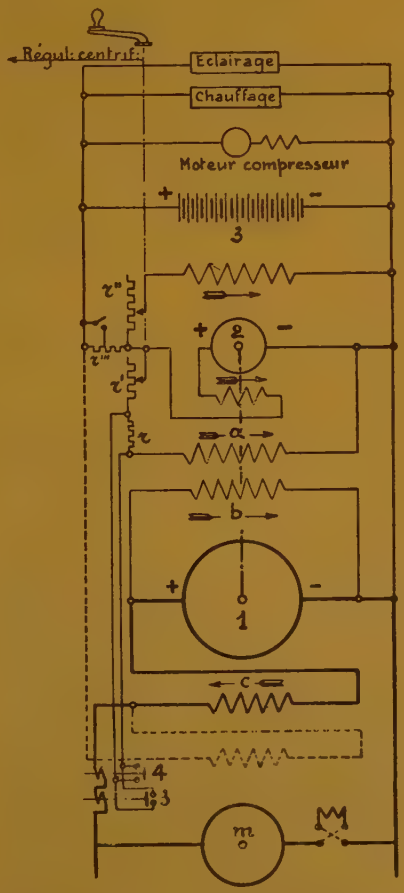


Fig. 57. — R. Z. M. transmission of the Deutsche Reichsbahn. — Principle of design.

Note : Regul. centrif. = centrifugal governor. — Eclairage = lighting. — Chauffage = heating. — Moteur compresseur = compressor motor.

— a shunt winding (*b*);

— a series winding (*c*) in opposition to the two preceding ones.

Through this arrangement, any increase in intensity of the main current causes a corresponding weakening of the field due to the separate — excitation and shunt — excitation windings. The voltage at the terminals of the main generator decreases very appreciably when the main current increases, and vice-versa, which makes the characteristic curve of the generator drop very sharply.

As in the Lemp system, the influence of the variation of the angular speed on the voltage at the terminals of the generator is also particularly marked, because the exciter being coupled to the shaft of the main generator, any voltage variation of the former of these machines accentuates the voltage variation of the other.

The R.Z.M. system is used by the Reichsbahn on a large number of railcars, some of which are already in service, but most of which are still under construction; these are :

— 13 eight-wheeled railcars with 300-H.P. diesel engines for the main lines (maximum speed 90 km. = 56 miles an hour);

— 103 eight-wheeled railcars with 410-H.P. diesel engines, for main lines (maximum speed, 110 km. = 68.3 miles an hour);

— 13 twin railcars (6 pairs of wheels), with two 410-H.P. diesel engines, for a maximum speed of 160 km. (100 miles) an hour.

— 2 triple railcars (on eight pairs of wheels) with two 600-H.P. diesel engines, for a maximum speed of 160 km. (100 miles) an hour.

5. A.E.G. system.

The A.E.G. Company, also inspired by the American « Lemp » system, have improved it in the following way (fig. 58).

The self-regulating generator (1) acts, as in the Lemp system, with separate excitation; but in principle the A.E.G. system has two exciters (2) and (3). One of the field windings (A) of the main generator is directly connected to the terminals of the two exciters in series, whereas the other (B), connected in parallel to the external circuit of the two exciters, is connected, as in the Lemp system, to the terminals of a battery of accumulators (4). The two exciters have a common field winding (*a*) fed by current from this battery.

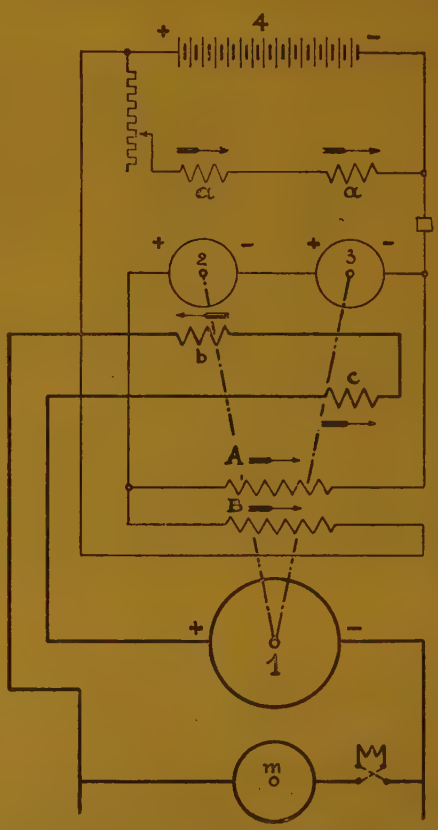


Fig. 58. — A.E.G. transmission with double exciter. — Principle of design.

One of the two exciters (2) is strongly

decompounded by the main current (winding *b*), whereas the other (3) is slightly compounded by this same current (winding *c*).

Under these conditions the decompounded exciter (2) produces a voltage the value and direction of which vary essentially with the intensity of the main current, while the compound exciter (3) supplies a practically constant voltage.

As a result of this arrangement :

a) When the intensity of the main current reaches an average value, the currents passing through the separate excitation winding (*a*) and the opposing winding (*b*) of the decompounded exciter (2) balance one another.

b) When, starting from its mean value, the intensity of the main current decreases, the influence of the current in the separate excitation winding (*a*) progressively exceeds the main current in the opposing winding (*b*). The anti-compound exciter (2) supplies an increasing voltage in absolute value, and of the same sign as the constant voltage supplied by the compound exciter (3) to which it is added.

c) When contrariwise, starting from its average value, the intensity of the main current increases, the opposite occurs : the influence of the opposing winding (*b*) becomes progressively the more important; the anticompounded exciter (2) supplies a still increasing tension in absolute value, but of contrary sign to that of the constant voltage of the compound exciter (3) from which it is then deducted.

The resulting voltage at the terminals of the main generator, thus obtained, varies with the intensity of the current delivered, according to a practically hyperbolic law.

So designed, this method of excitation enables the full power of the diesel to be used within large working limits, which explains the name of « Vollastschaltung » under which the A.E.G. present this design.

In recent cases in which it has been used (so called « with divided poles » type), the same company (A.E.G. in Germany, and G.E.C.O. in America) apply the principle described above, according to one or other of the two variants :

a) exciter with divided poles and main generator of usual type;

b) single exciter and main generator with divided poles.

This system will be applied in one of the *a* or *b* forms to the three fast triple railcars of the Belgian National Railways Company.

* * *

CHAPTER V.

HYDRAULIC TRANSMISSIONS.

With hydraulic transmission, the torque and speed of the secondary shaft can be varied continuously whatever the engine speed may be. It is based on the principle of the hydraulic turbine.

It consists of a torque converter and a coupling.

The *torque converter* consists of a centrifugal pump on the engine shaft and a hydraulic turbine, the moving vanes of which are secured to the secondary shaft whilst the fixed vanes form part of the casing.

The pump on the engine shaft acts as the generator and forces the oil through the turbine which functions as a receiver and drives the secondary shaft.

The coupling enables the engine shaft to be coupled to the secondary shaft in order to give direct drive, and is either hydraulic or mechanical.

The VOITH and LYSHOLM-SMITH hydraulic transmissions are described below.

Voith hydraulic transmission.

In the Voith transmission, the same casing contains two distinct units : a torque converter A, and a coupler B (fig. 59).

The converter A is made up of three parts :

— a centrifugal pump (1) keyed on the primary or engine shaft;

— a hydraulic turbine rotor (2) keyed on the secondary or driven shaft;

— a distributor or hydraulic turbine stator (3) the vanes of which are fastened to the casing.

The coupler B is a Föttinger hydraulic clutch and is formed of two symmetrical half tores, one (4) keyed to the engine

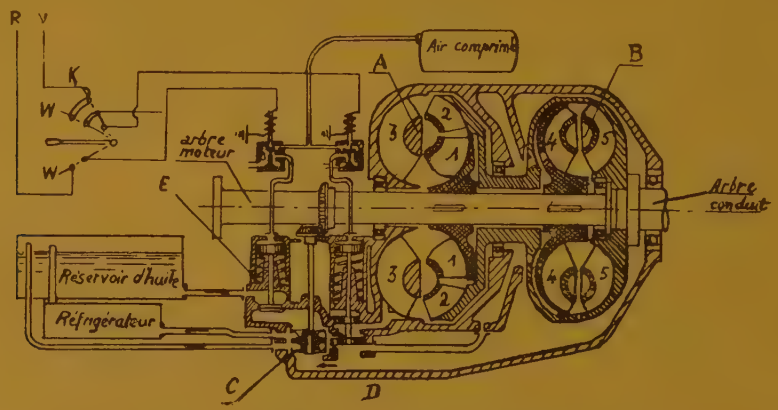


Fig. 59. — Longitudinal section of VOITH transmission.

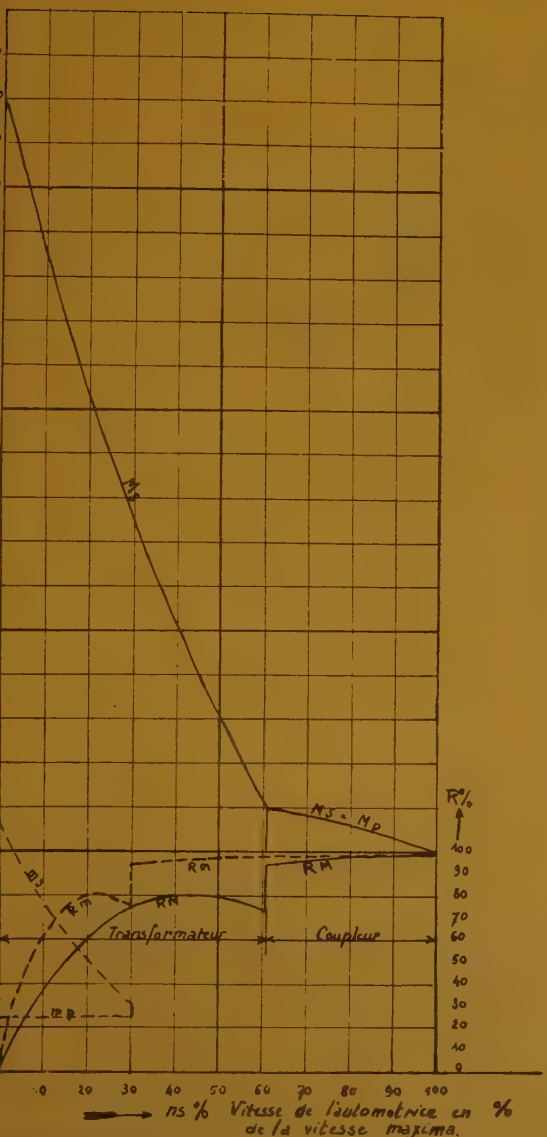
Explanation of French terms:
Air comprimé = Compressed air. — Arbre moteur = Main shaft. — Arbre conduit = Driven shaft. — Réservoir d'huile = Oil reservoir. — Réfrigérateur = Cooler.

shaft, and the other (5) fastened to the driven shaft.

A rotary pump C driven by the engine shaft recovers any leakage liquid and drives the oil through a cooler. By means of an electro-pneumatically controlled distributor valve, the oil can be sent either to the torque converter A, or to the coupler B. The passage from one to the other is practically instantaneous, and when this is taking place, it is not necessary to cut off the carburetter in the case of a petrol engine, or to reduce the injection on an oil engine. Finally by means of a clap valve, also electro-pneumatically operated, the fluid can be completely prevented from entering the transmission, and coasting is obtained without any ratchet device.

A 200-H.P. Voith transmission weighs 1 000 kgr. (2 200 lb) including the fluid, when the main shaft runs at 1 400 r.p.m., and only 400 kgr. (880 lb.) [fluid and multiplying gear included] when the primary shaft absorbs the same power of 200-H.P. at 2 900 r.p.m.

In order to save weight, the transmission for the German State Railways' rail-



Efficiency of Voith transmission without multiplying gear ————.

Efficiency of Voith transmission with multiplying gear - - - - - - - - -.

Fig. 60. — Voith transmission. Driving torque and efficiency in terms of the engine speed.

Note: Transformateur = Torque converter. — Coupleur = Coupler. — Vitesse de l'automotrice... = Speed of railcar, % of the maximum engine speed.

cars with 600-h.p. Maybach engines includes a multiplying gear combined with the reverse gear.

With the electro-pneumatic control of the distribution valve, which sends the oil to the converter or to the coupler, distant control of several sets of gears may readily be used.

The Voith transmission has been in use for over a year on a number of Austro-Daimler railcars fitted with petrol engines developing 80 to 90 h.p. at 3 000 r.p.m.

Some of these railcars are working under exceedingly difficult conditions on lines with heavy gradients, such as the Semmering line.

Three 160-200 h.p. sets of transmission gear have been delivered to the builders of railcars for the German State Railways, but the vehicles are not yet delivered.

Two 420-450 h.p. and seven 280-300 h.p. sets are being built at Heidenheim, also for the German State Railways, and two 105-h.p. sets for a Dietrich railcar for the French railways.

Finally, designs for four sets to work with the supercharged 600-h.p. Maybach engines for the German State Railways are in hand.

Lysholm-Smith hydraulic transmission.

This transmission is composed of a centrifugal pump the rotor C of which is secured to a sleeve B which carries a clutch plate A (fig. 61).

A turbine rotor D, with three rings of vanes free to turn, is connected to the secondary shaft S through a free wheel F. Two fixed rings H, solid with the outer casing, complete the turbine.

The transmission includes two clutch plates, one of which, A, is fastened to the pump rotor, and the other, K, to the secondary shaft. A single lever is used to take the drive through either plate K or A. When A is thrown in, the pump and the turbine come into action. If

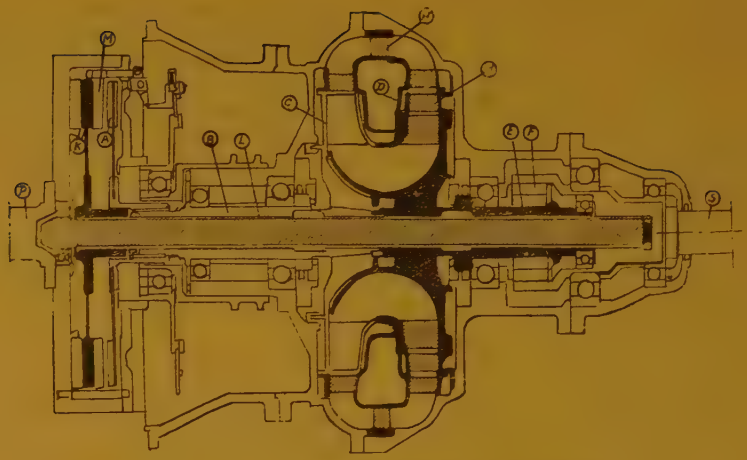


Fig. 61. — LYSHOLM-SMITH transmission.

however K is driving, the pump is no longer driven, and the turbine itself remains stationary as, thanks to the free wheel F, the secondary shaft is directly driven without the turbine rotor being driven at the same time.

This transmission gear is used on some railcars on the London Midland and Scottish Railway.

* * *

CHAPTER VI.

THE RUNNING GEAR and BOGIES OF RAILCARS.

A. — Wheels.

The wheels may be grouped into two classes :

1. Elastic wheels themselves subdivided into :

a) Wheels with elastic rims;

b) Wheels with rigid metal rims.

2. Rigid all-metal wheels.

1. *a*) *Wheels with elastic rims.*

The most widely used is the Michelin wheel employed on French railcars.

The main features may be recalled briefly.

These wheels are fitted with a pneumatic tyre adapted for running on rails (fig. 62).

The detachable wheel is made of pressed discs of the automobile type. The rim is extended on the inside by a flange in steel plate stiffened by corrugations. Its diameter is greater than that of the pneumatic tyre, and it is fitted with a steel ring which acts as the flange, and it is sound-deadened by inserting a rubber ring.

The pneumatic tyre is kept on the rim by an easily removed ring.

The tread is grooved to improve the adhesion.

A safety device is fitted inside the tyre and consists of a rigid ring of suitable section intended to prevent anything serious happening if the tyre becomes deflated or burst, by reducing the

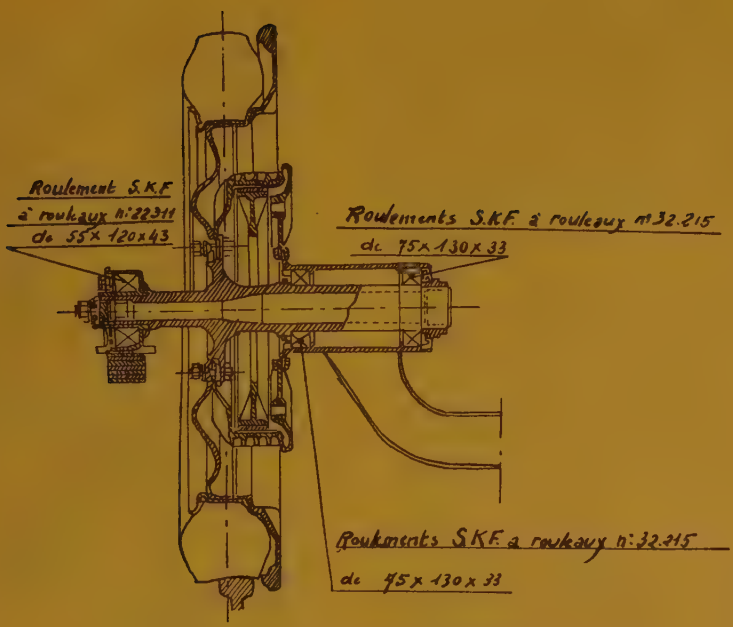

Roulement S.K.F
à rouleaux n°32311
de 55 x 120 x 43
Roulements S.K.F. à rouleaux n°32.215
de 75 x 130 x 33
Roulements S.K.F. à rouleaux n°32.215
de 75 x 130 x 33

Fig. 62. — Carrying axle and wheel of 36-seater MICHELINE.

Note: Roulements... = S.K.F. roller bearings.

amount the wheel can drop, to 1 cm. (3/8 inch).

The tyre pressure is about 7 kgr./cm² (100 lb. per sq. inch.).

The advantages of the Michelin wheel are well known :

— protection of the vehicle against shocks and vibrations, so that light construction is possible;

— absence of noise from tyres rolling on the rails;

— much greater adhesion between wheel and rail than with steel wheels.

It must be noted, however, that owing to the narrow bearing surface (4 to 5 cm. = 1 3/4 to 2 inches) the wheel load is limited. Moreover the use of pneumatic tyres between the mass of the vehicle and the files of insulated rails, together with the low weight on the wheels, have made it necessary to design special devices for short-circuiting the track. Finally, the use of the Michelines also makes it necessary to alter somewhat the design of detonators.

b) Elastic wheels with rigid metal rims.

The feature of these wheels is the interposition of some elastic medium between the wheel centre and the tyre.

Two classes of wheels are to be considered :

— those with a ring or band of rubber providing *radial elastic connection and at the same time lateral elastic connection* between the rim and the wheel centre;

— those in which these two requirements are met by *separate* elastic devices, one to give *radial* and the other *lateral* flexibility.

The first group includes the elastic wheel reported by the Bergslagen Railway (Sweden), which wheel has two rubber rings between the tyre and the wheel centre. The tyre and centre are held together by bolts and a steel retaining ring.

The wheel used by the Austro-Daimler Company, which deserves a special description, can be included in the same group.

This wheel has a pneumatic tyre inside a steel drum fastened to a rigid metal wheel with a tyre and flange (fig. 63).

The two steel wheels of a set are carried and connected together by a crank axle which keeps them the correct distance apart.

The vehicle is supported on these wheels through a straight carrying axle and wheels with pneumatic tyres.

The result is that vertical thrust and side shocks exerted by the track on the steel tyre are damped out by the pneumatic tyre.

The pressure in the pneumatic tyres is 2.5 tot 3 kgr./cm² (35.5 to 42.7 lb. per sq. inch).

From a practical point of view, the Austro-Daimler wheel has the following features :

— the pneumatic tyre has a large bearing surface and can be loaded up to 3 000 kgr. (6 600 lb.) per wheel;

— the wear of the pneumatic tyre is reduced through running on a perfectly smooth surface;

— the cost of two concentric axles is comparatively high.

The second class of wheels includes the following :

L. B. (Bacqueyrisse) wheel
(fig. 64).

This wheel, which is used on the de Dietrich railcars, has a rubber ring A

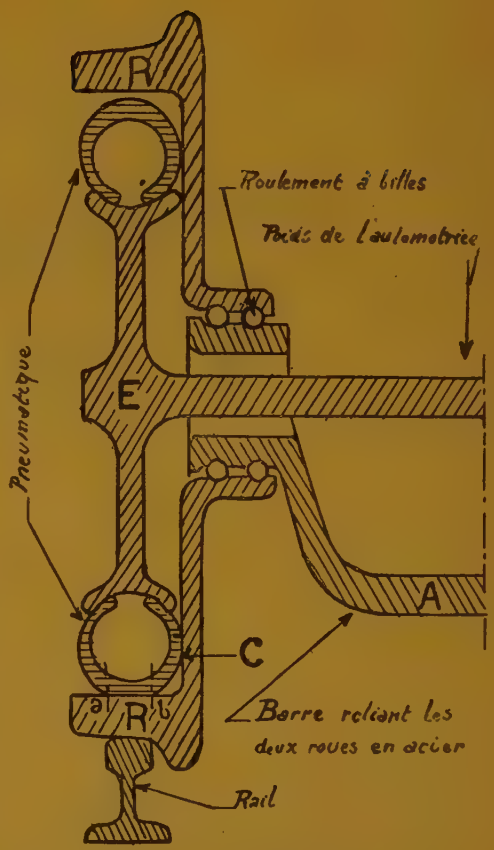


Fig. 63. — DAIMLER wheel.

Explanation of French terms :

Roulement à billes = Ball bearing. — Poids de l'automotrice = Weight of railcar. — Pneumatique = Pneumatic tyre. — Barre reliant... = Bar connecting the two steel wheels.

compressed between the centre and the tyre. Its function is to damp out radial shocks. Two other rubber rings C are also held in place on the sides of the wheel centre by manganese silicon steel plates, and provide a lateral elastic connection.

The three rings A and C all play their part in providing the necessary con-

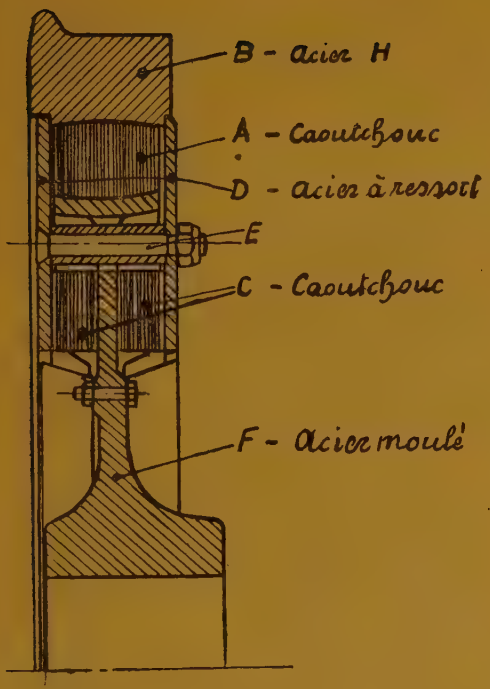


Fig. 64. — Elastic wheel, L. B. system.

Explanation of French terms:
Acier = Steel. — Caoutchouc = Rubber. — Acier à ressort = Spring steel. — Acier moulé = Cast steel.

nection between the tyre and centre in order to deal with the tangential forces due to the tractive effort and to braking.

Bugatti wheel.

Three rubber bands, tightly pressed against one another, are inserted between the tyre and the wheel centre to damp out vertical vibrations.

The tyre is bolted to the centre by bolts with rubber ferrules to damp out the vibrations that might be set up in driving the wheel.

Rubber rings are used to damp out the lateral shocks.

S.O.M.U.A. wheel.

The tyre is connected to the wheel centre disc by pins working in silent-blocks.

Indiarubber washers are fitted on the silent-blocks between the collar of the tyre and the discs and provide lateral elasticity.

* * *

Elastic wheels have the advantage of damping out, at least partly, the vibrations and shocks experienced in running and therefore help to give greater comfort. They have the disadvantage of greater weight and cost, and involve special equipment for short-circuiting track-circuited rails.

2. *All-metal rigid wheels.*

The one-piece wheels are cast or forged steel wheels, usually with thin tyres.

The one-piece wheels under certain RENAULT railcars are fitted with an anti-noise ring of rubber, bolted to the centre, intended to damp out the vibration of the wheel itself.

Wheels with separate tyres. — Most of these are of the classic railway type with lightened tyres secured by Gibson rings to cast or forged steel centres.

The diameter on the tread is usually 850 to 970 mm. (2 ft. 9 1/2 in. to 3 ft. 2 1/4 in.). Diameters less than the U. I. C. sizes are in use, however. The Bugatti wheel is only 710 mm. (2 ft. 4 in.), and the Breda 700 mm. (2 ft. 3 1/2 in.). The Belgian National Railways Company has adopted the diameter of 970 mm. (3 ft. 2 1/4 in.) for railcars.

The tyres are usually thinner than the usual 75-mm. (2 61/64 inches) used on

carriages and wagons. The Belgian National Railways Company uses 50-mm. (1 31/32 inches) tyres on its railcars, the same thickness as is used on the « Schnelltriebwagen ». The de Dietrich railcar, which is fitted with brake drums and the tyres of which consequently wear very little, have been made only 40 mm. (1 37/64 inches) thick.

Now, a reduction of 25 mm. (63/64 inch) in thickness means a saving of some 600 kgr. (1 320 lb.) in the case of a bogie rail motor car.

One-piece steel wheels are of forged tyre steel or special steel, such as nickel-chrome-molybdenum, for example.

In wheels with tyres, cast or forged-steel centres are used, sometimes made of special nickel-chrome steel, and the tyres are of carbon steel of the usual tyre steel quality.

Flange lubricators to reduce flange wear on curves are far from being generally used.

Tyre contours.

The tyre contour generally used on railcars is the ordinary carriage tyre contour.

It has been found, however, that at very high speed some hunting takes place, especially on the straight, when the flange is not held against the outer rail by centrifugal force.

Several railways have endeavoured to cure this defect by changing the contour.

The Reichsbahn, the Danish State Railways, and the French Railways have carried out tests with different contours (standard, cylindrical, 1 in 40 slope).

Unless the results of the tests in hand show otherwise, it would appear that the 1/40 contour gives better results than the ordinary contour.

The question, however, is to find a contour which gives good riding at very high speed, with minimum tyre wear.

B. — Axle boxes.

Roller bearing axle boxes are generally used for both driving and carrying axles.

Two types are in use :

— automobile type or special boxes;

— railway boxes like those used under carriages.

The first group includes the Bugatti box for fixed axles, and the Somua box used on the Paris-Lyons & Mediterranean's four-wheeled railcar.

The second group covers the boxes of most bogie railcars.

It should be noted that the Isothermos box is used on a number of such vehicles.

C. — Axles.

The axles are either the automobile type with wheels running freely on fixed axles and the driving wheels keyed or shrunk on the axle or driving shaft, or, more generally, the railway type with the wheels pressed on hot.

The automobile type axles are generally in use on light four-wheeled railcars. The driving axle then follows the design of an automobile rear axle, but without differential. Examples are : the Bugatti loose wheel, the driving axle of the Somua for four-wheeled railcars, the loose and driving wheels on the Bergslagen Railway (Sweden), and the driving axle on the Decauville bogie axles on the Dutch triple railcars.

Most heavy bogie railcars have railway-type axles of reduced section, thanks to the use of special steels such as nickel-chrome.

Hollow axles are sometimes used, as for example the de Dietrich driving axle in nickel-chrome steel, and the axles on the Dutch triplets.

The body of the Somua railcars is carried on four laminated springs supported by the frame through shackles. The wheels are guided by these springs, no axle guards being used. Silent-blocks

are used throughout the spring gear. Shock absorbers between the frame and axles damp out the oscillations.

The Decauville railcar bogies are not fitted with axle guards; each axle is, in fact, like the trailing axle of an automobile, but without the differential. The bogie rests on these axles through four laminated springs, with slightly reversed camber, fastened under these axles. The suspension links are fitted with silent-blocks. These axles are connected to the bogie sole bars by links to take the braking thrust and reaction.

Most railcars are, however, fitted with axle guards to guide the axles, the boxes sliding in the guards being given suitable lateral and longitudinal play. Long laminated carrying springs are used.

The railcar built by Les Entreprises Industrielles Charentaises is unusual in that the body is carried on four pairs of wheels and not on bogies. The wheels are connected in pairs by equalizers carried on the roller bearing axle boxes. The outer axles are given some play to facilitate running through curves.

The railcar built by the Compagnie Générale de Construction also has some peculiar features. The body is carried on the two pairs of wheels through laminated springs 2 m. (6 ft. 6 3/4 in.) long. The boxes are carried on two bissel trucks which enable the axles to adapt themselves to the track. The side play, limited by stops, is 33 mm. (1 19/64 inches) each side. Adjustable stops are provided for limiting this play in the case of the leading axle.

Wheel base of four-wheeled vehicles.

In order to improve the passengers' comfort in four-wheeled railcars, the wheel base should be increased. This, however, is limited by curve negotiating conditions. The limiting wheel base appears to lie somewhere about 8.50 m. (27 ft. 11 in.).

The four-wheeled Ganz railcars have a wheel base of 8.50 m. (27 ft. 11 in.); the four-wheeled railcars of the Entreprises Industrielles Charentaises (Paris-Lyons-Mediterranean) have a wheel base of 8.03 m. (26 ft. 3 in.).

D. — **Railcar bogies.**

Like carriage bogies, railcar bogies should comply with the following conditions :

A) — not to transmit to the body, or at least to damp out, the reactions resulting from running onto curves, and from irregularities in the track, both longitudinally and transversely;

B) — to avoid hunting movements.

The problem to be solved is, however, more complex, because :

— in most cases railcars run by themselves;

— certain of the wheels of the bogie are used to propel the railcars;

— the railcar bogie can in certain cases be used to carry bulky and heavy equipment (diesel, petrol or steam engines, gear boxes, electric generators, electric motors);

— the heaviest bogie of a reversible railcar with a single driving bogie is at the leading or trailing end of the vehicle, according to the direction of running, so that the railcar is sometimes hauled and sometimes pushed.

Use of bolsters.

In the early days of railcars, the builders used bogies with bolsters almost exclusively; to lighten and simplify the construction some builders have endeavoured to do away with the bolster, and it must be admitted that contrarily to what was expected by many, the results, without being perfect, are as a rule, acceptable in practice.

In fact, it is not certain at the present time that the bolster will be retained on future rolling stock, and it is necess-

ary to wait until systematic tests have been carried out to decide which is the better of the two systems.

In the case of bogies with bolsters, the latter are free to move up to over 20 mm. (25/32 inch) each side of the centre line.

It has never been demonstrated, however, that this lateral play is essential, and many builders think it harmful, although other builders recommend it with dampers to reduce the movements of the bolster.

In the case of bogies without bolster, there is no lateral displacement of the centre, the exceptions being the Renault bogie and the Decauville bogie.

Bogies without bolsters are fitted with elastic slides which act as equalizers to the body, whilst the bogies with bolsters are fitted with ordinary slides on which the play between the rubbing blocks varies from 1 1/2 to 5 mm. (1/16 to 3/16 inch), according to the builder.

Centre pin.

The centre pin of driving bogies is often eccentric by about 0.40 m. (15 3/4 inches). The maximum eccentricity is that of the Decauville bogie, on the French Nord railcars where it is 0.90 m. (35 1/2 inches); no drawback has been experienced therefrom.

Wheel base.

Generally speaking, the bogie wheel base lies between 2.30 and 3.60 m. (7 ft. 6 9/16 in. and 11 ft. 9 3/4 in.); driving bogies carrying diesel engines are necessarily given a longer wheel base than that of the ordinary carrying bogies [some Jugoslav railcars have driving bogies with a 5.60 m. (18 ft. 4 1/2 in.) wheel base].

Use of rubber.

The use of rubber blocks to deaden noise and damp out vibrations is very general. They are used : as auxiliary suspension springs, under the spring buckles carried on the axle boxes, under the centre bearing, under the slides, and as silent-blocks in the knuckle joints. Certain companies, however, think that rubber, far from damping out vibrations, sets up at certain times harmonic vibrations, the frequency of which is eight or ten per second, which are disagreable for the passengers.

Shock absorbers.

Shock absorbers are used on railcars in two ways :

1. to damp out the spring gear;
2. to damp out hunting of the bogie.

Most of the existing devices can be used in both ways, and frequently the same equipment can meet both requirements. In both cases, the shock absorbers are used to prevent harmful resonance being set up, which detracts from the comfort and from good riding on the road.

Among shock absorbers used on railcars, friction shock absorbers, hydraulic shock absorbers, and shock absorbers combining the two principles, may be mentioned.

Although most shock absorbers used on railcars were designed for automobile use, and therefore cannot absorb sufficient energy, the results obtained are encouraging and it is to be expected that progress in this direction will make railcars more comfortable.

* * *

Description of the bogies used on railcars.

The bogies examined can be grouped into two classes :

1. — Bogies of special type.
2. — Bogies derived from types used under carriages and wagons :

a) Wagons-lits (Sleeping-Car) type;
b) Pennsylvania type;
c) Görlitz type;
d) Single suspension bogies.

1. Special type bogies.

Amongst these, mention may be made of the Bugatti and Michelin bogies.

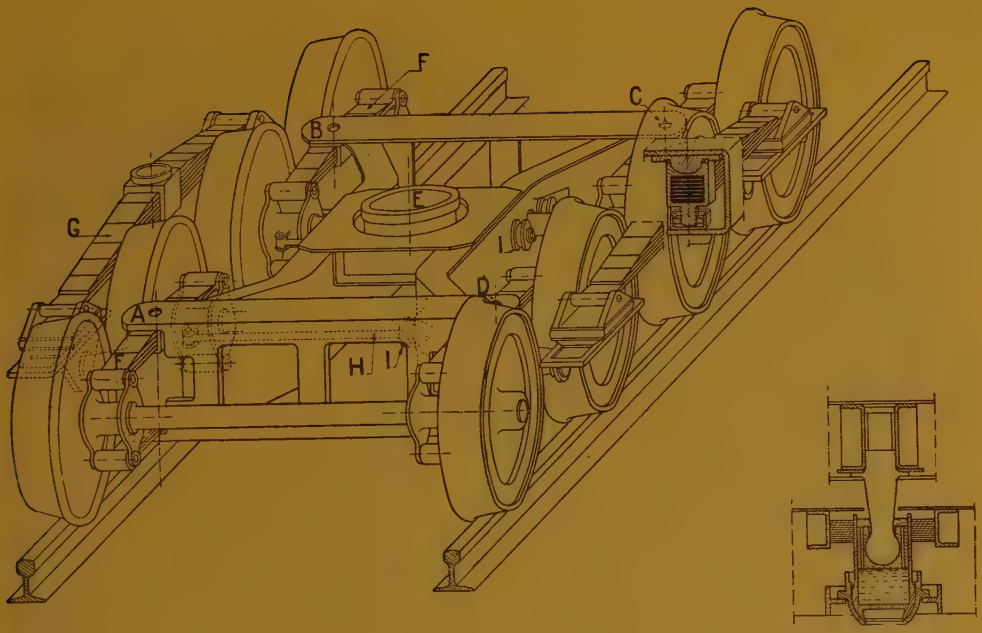


Fig. 65. — Bugatti bogie with details of centre.

Bugatti bogie.

The driving bogie of the Bugatti rail-cars has four pairs of wheels, the two middle pairs being drivers and the two outer carrying.

On the frame of forged steel are carried at A, B, C, D, (fig. 65), four groups each of two laminated springs, which can turn at these points around a vertical axis; the knuckle joints connecting the axles with the ends of these springs are fitted with « silent-blocks » so that each pair forms with the springs a parallelogram which can be deformed horizontally.

The body is carried by each bogie through longitudinal laminated springs arranged alongside the sole bars; the buckle of these springs is connected to the body by a spherical bearing at the top, and at the bottom by a pin sliding in a guide parallel to the centre line of the vehicle.

The ends of the springs carry shoes which rest on bronze guides fixed to the bogie frame; blocks of rubber are interposed between the springs and the shoes.

The bogie centre is only used to guide the bogie, and does not carry the weight of the body; it is formed of :

— a vertical cylinder filled with oil, resting on the bogie through a spherical centre and kept in place laterally by rubber blocks;

— a piston fixed to the frame by a ball-and-socket joint moving in the cylinder.

This piston is drilled with holes so as to let the oil gradually pass through it when vertical oscillations are set up, in order to damp out the latter.

The wheel base is 2.70 m. (8 ft 10 5/16 in.).

Fig. 66. — Driving bogie of 56-seater MICHELINES.

Bogies of the Michelines.

Messrs. MICHELIN have designed special bogies for different classes of rail-cars; most of these bogies have already been described in the technical press, so that we will only describe the bogie of the new 56-seater Michelines.

The underframe-body unit is carried on each bogie frame on four bronze supports or by links (fig. 66); it is secured to the bogie frame by a pivot.

The bogie frame is welded steel plate; the springing consists of four complete laminated springs. These springs, rigidly secured at their centres to the bogie frame, rest on the axles on bronze guides.

2. Bogies derived from types used under carriages and wagons.

a) Wagons-lits (Sleeping-Car) type bogies.

The following is a description of a certain number of bogies which may be taken as being derived from sleeping-car bogies.

These bogies are carried on two pairs of wheels with a wheel base of 2.40 m. (7 ft. 10 15/32 in.); the center pin is on the centre line; each carries two electric traction motors.

They are built up of plates and rolled sections assembled by riveting.

The bolster is suspended from the bogie frame by inside links on knife edges.

Fig. 67. — Bogie with one 140-H.P. engine, on the railcar built by the « Compagnie Française de Matériel de Chemins de fer ».

Bogies of the « Compagnie Française de Matériel de Chemins de fer « (French Nord Railway).

These bogies carry a diesel engine, a generator, and an electric motor driving one of the axles.

The cast steel one-piece frame (fig. 69) is carried on the boxes by laminated springs and rubber shock absorbers.

The body is connected to the frame through a bolster; there are two groups of elliptical springs between the body bolster and the bogie bolster.

The body is carried on the body bolster by a centre pin and spherical seating, and slides without any spring centering device.

The bogie bolster is of the usual design with the bolster carried by short links with round pins. In addition to the elliptical springs mentioned above, a large rubber pad is fitted under the centre to which it is bolted, the bolts being fitted with rubber washers.

Bogies of the Italian State Railways' Breda railcars.

The sole bars and cross bearers of these bogies are in steel pressings electrically welded together; the bolster and the cross stays are also made of steel plate electrically welded.

The bolster is carried on forged steel braces (fig. 68). The elliptical springs carrying the bogie bolster are of special spring steel.

The frame is spring-supported on the axle boxes through parallel laminated springs. Rubber blocks, to damp out vibrations, are fitted between the axle boxes and the spring hangers, between the spring links and spring hanger brackets.

Brill bogies.

The bogies used by Messrs. J. G. Brill on some railcars (Congo-Océan — Provence Railways — Ferrovie Calabro-Lucano) can be included among the sleeping-car type.

These bogies have the following characteristics :

1. The bogie bolster is carried by elliptical springs on members arranged parallel to the sole bars (fig. 69), and suspended from the latter by articulated links fastened as near as possible to the boxes.

2. The bogie frame is supported elasti-

Fig. 68. — Bogie with one 130-H.P. engine, of the BREDA railcars, Italian State Railways.

cally on the axle boxes through coiled springs resting on the top of the boxes.

The side movements of the bolster are damped by an arrangement which sets up additionnel friction at the swing link pin, and by a method of guiding and moving the bolster whereby the bolster springs are at all times free to act in the vertical direction and are not subject to any other forces.

b) Pennsylvania type bogies.

The bogies of many railcars can be classed with this kind of bogie. A description of some such bogies is given below.

Bogies of the Dutch triplets.

The Dutch triplets have four bogies, the two outer bogies are four-wheeled carrying bogies, and the two six-wheeled middle bogies are driving bogies.

Figure 70 shows one of the driving bogies of these railcars.

The weight of a carrying bogie is 4 900 kgr. (10 800 lb.).

The weight of a driving bogie is 7 580 kgr. (16 700 lb.) without the two traction motors which weigh 3 100 kgr. (6 830 lb.).

C. K. D. and Skoda railcar bogies of the Czechoslovak State Railways.

The driving and power bogies of these railcars are of the Pennsylvania type.

The bogie bolster has a play of one millimetre (3/64 inch) longitudinally

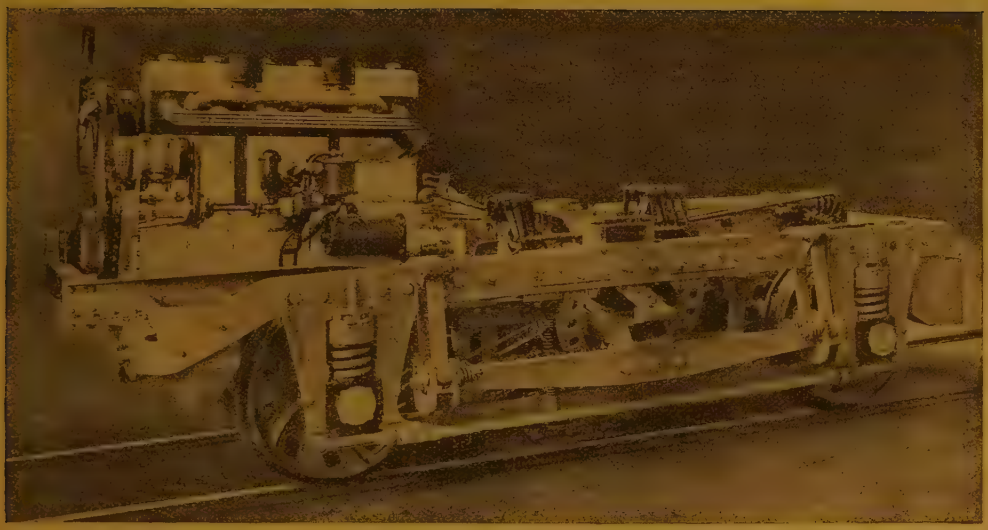


Fig. 69. — BRILL bogie, with one 125-H.P. engine, of the Congo-Océan railcars (metre gauge).

Fig. 70. — Driving bogie of Dutch triplets.

and 23 mm. (29/32 inch) laterally on each side of the centre line.

Figure 71 shows a driving bogie of the CESKOMORAVSKA-KOLBEN-DANEK railcars.

Renault bogies.

Messrs. RENAULT use a Pennsylvania type bogie with 3 m. (9 ft. 10 1/8 in.)

wheel base as the middle carrying bogie of their twin railcars.

Carrying bogies of the « Aciéries du Nord » railcars, Paris-Lyons-Mediterranean Railway.

The « Aciéries du Nord » have used bogies of the Pennsylvania type for the railcars built for the Paris-Lyons-Mediterranean Railway (France).

c) Goerlitz type bogies.

The bogies under many railcars in most countries come under this heading. The Goerlitz bogie is actually an excellent design when diesel engines and transmission gear, whatever the type, have to be fitted between its two sole bars.

Bogies of the « Schnelltriebwagen ».

This twin railcar is carried on three bogies, the two outer being power bogies, the middle one being the only driving one, with each axle driven by an electric traction motor.

The bogie frame is built up of plates and rolled sections welded together, and is carried on four laminated springs with square-section auxiliary steel coiled springs.

The body is carried on a bolster over the frame in the case of the power bogie. The ends of this bolster are carried on two longitudinal springs attached to the frame by adjustable shackles.

This railcar is braked in rather a special way. The Knorr automatic air brake is used. A brake cylinder is fitted for each brake shoe, to which it applies the effort through a short lever. These shoes, two per wheel, brake the outside of the cast steel brake drums bolted to the wheel centres.

The outer power bogie by itself (without diesel engine and generator) weighs 7 155 kgr. (15 770 lb.), and 13 t. (12.8 Engl. tons) in running order.

The centre bogie by itself weighs 7 630 kgr. (16 820 lb.) and 13.6 t. (13.4 Engl. tons) in running order.

Bogies of the de Dietrich railcar.

The two identical bogies (fig. 72) fall into the group of driving bogies carrying the diesel engine which drives one axle directly.

These bogies are of the usual design although the laminated bearing springs are carried under the axle boxes.

Houdaille shock absorbers are provided between the bogies and the body in order to damp out the hunting movements of the vehicle. It weighs 5 800 kgr. (12 780 lb.).

Bogies of the Brno-Kralovopolska railcars of the Czechoslovak State Rys.

The driving bogie of these railcars is of the usual type; it is shown in figure 73. It carries the 8-cylinder V-fashion diesel engine, the electric generator and the traction motor.

Aciéries du Nord bogies.

This firm built, for a number of railcars ordered by the various French railways, bogies of the Goerlitz type, which, however, materially differ from the classic design.

Some of them have a bolster, the others have none, but instead have long longitudinal laminated springs on which the body is suspended relatively to the bogie frame.

In the last category, may be classed the bogies of the French State and P.O.-Midi railcars as well as the so-called « Standard » railcars now under construction for the Est, Nord and P.O.-Midi Systems (fig. 74); in these railcars the bogie frames are carried on the roller-bearing axle boxes by laminated springs, and the body rests on the bogie frames through longitudinal laminated springs secured to the frame.

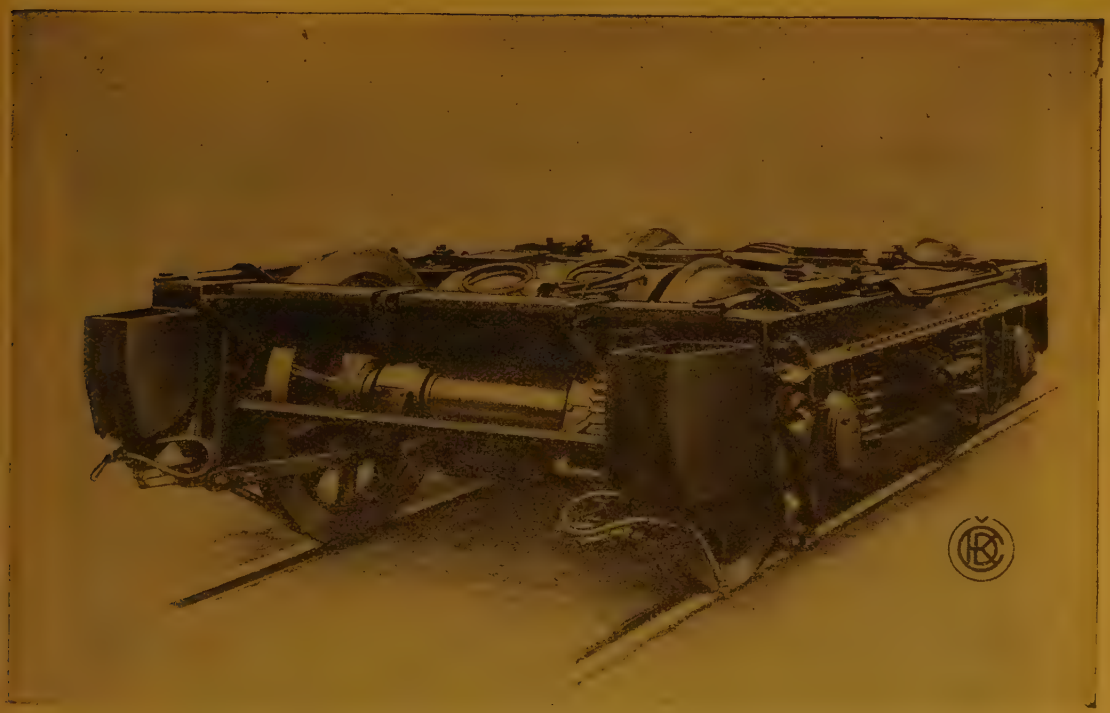


Fig. 71. — Driving bogie of C.K.D. railcars, Czechoslovak State Railways.

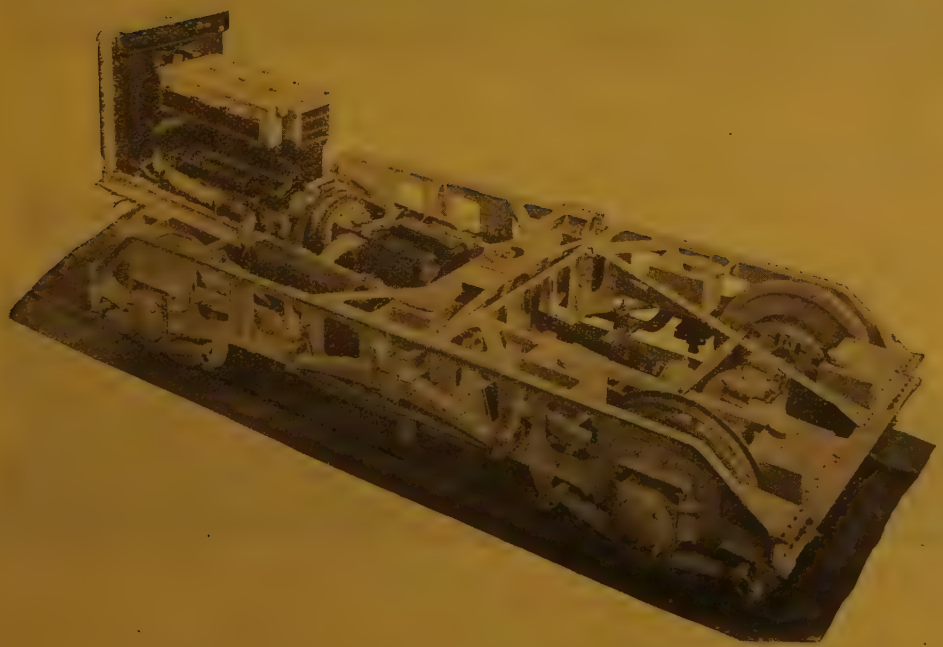


Fig. 72. — Bogie carrying one 105-H.P. engine, DE DIETRICH railcar.

Fig. 73. — Driving bogie, with one 160-H.P. engine, of the BRNO-KRALOVOPOLSKA railcars, Czechoslovak State Railways.

Fig. 74. — Bogie of A.D.N. railcars of the French State and P. O.-Midi Railways. Also of the so called « Standard » railcars supplied to the Est, Nord and P. O.-Midi Railways.

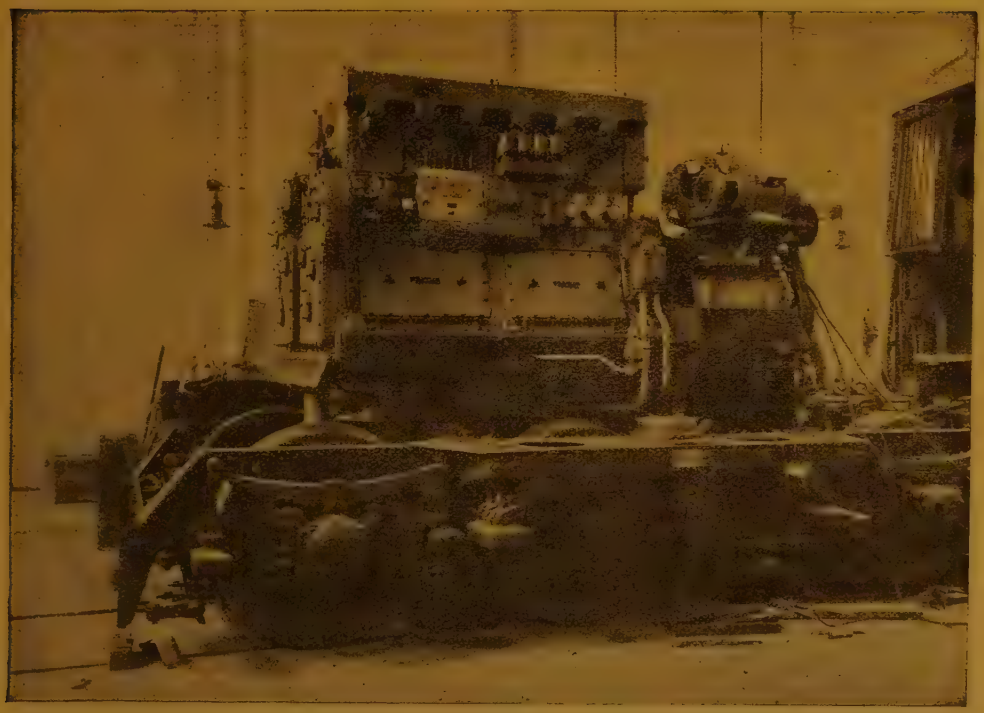


Fig. 75. — Six-wheeled bogie, carrying two 220-H.P. engines, of the FRICHS railcars (Danish State Railways).

The buckle of these springs has a pin with spherical bearing, which ends in a guide shoe rubbing againts the body.

The body is furthermore bolted to the ends of the cast steel body bolsters (one per bogie), which carry at the centre a spherical knuckle joint in nitrided steel, pivoting about a pin held at the top and bottom in the fixed central bogie bolster, the latter also in cast steel.

Bogies of the Frichs railcars.

Figure 75 shows the 6-wheeled driving bogie of the latest 440-H.P. railcars introduced in 1934 on the Danish State Railways. This bogie carries two 220-H.P. engines placed side by side, each with their generator on their main shaft.

The power set is raised so as to be on the same level as the floor, in order to facilitate inspection of the engines and generators.

Driving bogies of the Maybach 210-H.P diesel railcars of the Belgian National Railways Company.

These bogies (fig. 76) may be considered as falling into the Görlitz group. The frame is carried on laminated springs. The body is carried by the frame through longitudinal laminated springs with the ends attached to the body and not to the bogie frame as formerly.

The buckles of these springs are fitted

with slippers working on slides on the bogie frames.

The body bolster carries a pin held fast at its lower end about which a spherical bearing rocks (like the one described above).

The way the wheels are driven by a jack shaft, rods and crank should be noted.

d) Bogies with single spring gear.

These bogies are not fitted with bolsters nor with any secondary suspension.

The bogie frame is carried by four

Fig. 76. — Bogie carrying one 210-H.P. engine, MAYBACH diesel railcars of the Belgian National Railways Company.

laminated springs resting on the boxes or bolted under them.

The body is carried on a centre and side friction blocks. The latter are fitted with springs to balance the body.

Fiat bogies.

One of these bogies (fig. 77) is a driving bogie carrying a petrol engine driving one axle. The other is simply a carrying bogie.

The bogie frame is suspended by means of a rather special arrangement including four laminated springs with helical-spring shock absorbers.

The body is carried on the bogie by a centre with roller side bearings.

The wheel base is 2.80 m. (9 ft. 2 1/4 in.) to 3 m. (9 ft. 10 1/8 in.) according to type.

The bogie centre pin is eccentric.

Renault bogies.

The bogie is carried on the boxes by reverse-camber laminated springs with auxiliary shock absorbing springs consisting of piled-up rubber rings.

Rubber rings are inserted between the spring buckles and the axle boxes.

The body is carried on a centre pin with a large block of rubber between the centre and the bogie, which allows

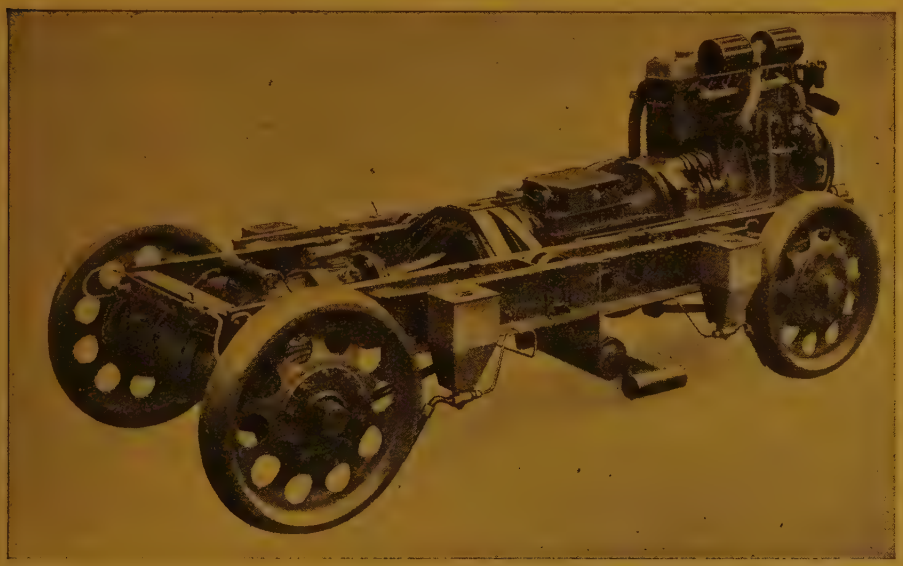


Fig. 77. — Bogie carrying one 120-H.P. engine, of the FIAT railcars.

25 to 30 mm. (1 in. to 1 3/16 in.) play on each side of the centre line and plays the part of a bolster. This centre is braked by two shock absorbers.

The side checks are elastic; a spring holds a shoe lined with ferodo against a friction block on the bogie frame.

These side checks help to balance the body and reduce hunting of the bogie.

Hungarian Railways' bogies.

The bogie frame rests on groups of helical springs carried on two levers fastened under the boxes.

The body is carried on the frame by a centre and side bearings.

Rubber shock absorbers are fitted over the helical springs, under the spherical centre, and under the side bearings.

To damp the oscillations of the helical springs, the axle boxes and guards have been given large guiding surfaces.

* * *

To sum up, it would be premature to decide in favour of any particular type of bogie. The Companies should carry out systematic trials on a given railcar in order to ascertain the favourable or unfavourable influence of the different factors.

* * *

CHAPTER VII.

RAILCAR BRAKES.

The braking of railcars is a problem of some complexity, as these vehicles are operated under very special conditions. The railcar represents both automobile and railway practice, and this explains why the brakes used may be of the :

— automobile type,
— railway type, or
— combined type, partly automobile, partly railway.

Some designers have even adapted to railcars the brakes used on aircraft (Charlestop brake, for example).

Railcars being intended to run alone, without a trailer, or with special trailers, their brakes need not be designed to work in conjunction with other brakes and for braking long rakes of stock. This explains why the choice of the brake is much less limited than in the case of ordinary railway vehicles and it is the reason for the diversity of the designs in use on railcars.

A railcar is generally fitted with a service brake, an emergency brake, and a standby brake. This is not an absolute rule, as if a service brake is naturally always fitted, this is not so with the other two. In certain cases the service brake can take the place of the other two. The most general arrangement of these three classes of quite distinct brakes will be considered in turn.

1. *Service brake.*

Railcar service brakes are almost always compressed-air brakes, which differ by :

— the way the compressed air acts;
— the nature of the friction surfaces between which the braking action occurs, and finally,
— the way the initial braking effort is transmitted to the friction surfaces.

a) Action of the compressed air.

The initial braking effort is always produced by admitting compressed air into one or several brake cylinders, in one of the two following manners :

1. directly, that is to say without using a distributor, with the *direct brake;*

2. through a distributor, which admits air from an auxiliary reservoir in each vehicle, into the brake cylinders, in the case of the *automatic brake.*

b) Nature of friction surfaces.

From this point of view there are two quite distinct classes of brake. Those with which the friction occurs :

1. between cast iron blocks carried on the frame, and the steel tyres of the wheels (block brake). This is the *standard railway method;*

2. between drums fastened to the wheels and articulated grippers or segments lined with woven or moulded asbestos carried on a plate fastened to the axle casing or the axle box. This is the *standard automobile method.*

c) Transmission of the braking effort.

The initial braking effort on railcars is transmitted in one of the following principal ways :

1. ordinary mechanical transmission by brake gear of the railway type, or by cables;

2. decentralised mechanical transmission, that is to say using a number of cylinders acting directly and individually upon each brake block or segment;

3. fluid transmission on the following principle : The compressed air piston operates a pump which compresses a fluid. By means of suitable flexible piping, the fluid under pressure is admitted into small cylinders operating directly and individually the brake

blocks or segments (Lockheed brake, for example).

To sum up, and as a result of the variations of the above mentioned characteristics, the different service brakes used on railcars may be classified as follows :

- Compressed-air brake
  - direct
    - blocks
      - ordinary mechanical transmission,
      - decentralised mechanical transmission,
      - fluid transmission.
    - drums
      - ordinary mechanical transmission,
      - decentralised mechanical transmission,
      - fluid transmission.
  - automatic
    - blocks
      - ordinary mechanical transmission,
      - decentralised mechanical transmission,
      - fluid transmission.
    - drums
      - ordinary mechanical transmission,
      - decentralised mechanical transmission,
      - fluid transmission.

Each of the brakes represented above can be controlled in several ways : by a driver's valve, or by a reaction brake foot pedal so arranged that the driver can feel the braking effort exerted, or by lever.

* * *

Comparison between the block brake and the drum brake.

Blocks acting on the tyres.

Let Q = the constant maximum pressure between the friction surfaces,
F = coefficient of friction between these surfaces,
P = weight of the braked vehicle,
Φ = coefficient of adhesion between the wheel and the rail.

As is known, if skidding is to be avoided : $Q F \leqslant P \Phi$ or $Q \leqslant P \frac{F}{\Phi}$.

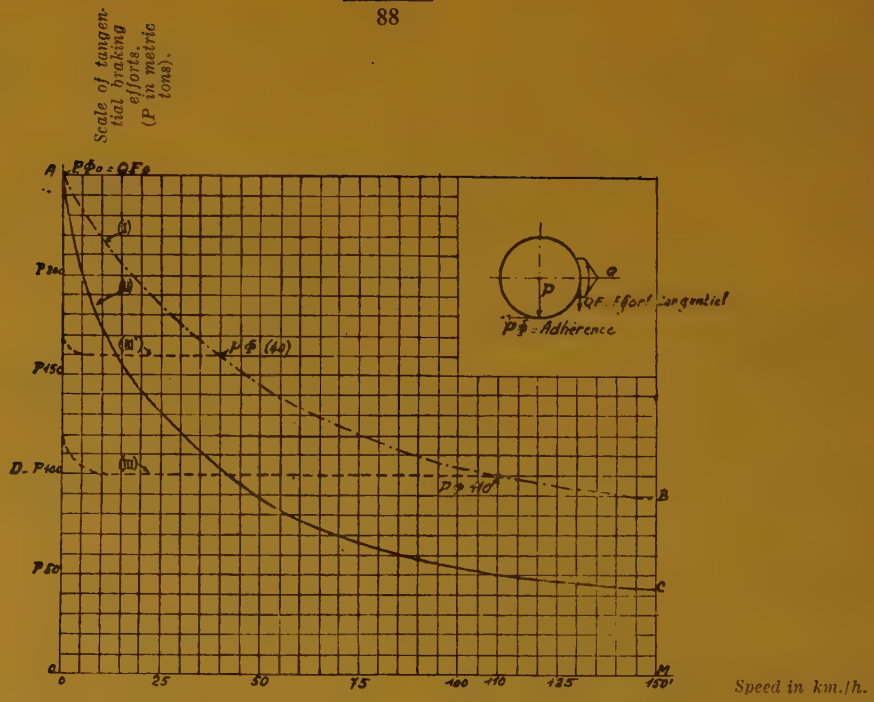
Now, when the block brake is used, the coefficient of friction between the blocks and the tyre increases considerably as the speed of the braked vehicle falls, and as this increase is much greater than the simultaneous increase of the coefficient of adhesion, the result is that QF increases much more quickly than $P \Phi$ as shown by figure 78, given by Mr. Bordes at a lecture before the Société des Ingénieurs Civils, Paris.

Consequently, the more the speed of the braked vehicle drops the greater the tendency to skid; to prevent this, Q must be given such a value that this skidding cannot occur except on coming to rest, i. e. when

$$Q F_0 = P \Phi_0 \qquad Q = P \frac{\Phi_0}{F_0}.$$

The pressure Q so obtained is much lower than the pressure that can be used without any danger of skidding at the maximum speed of the vehicle. At high speeds, the braking is therefore much less than the maximum possible, and this prevents us from getting the shortest possible stopping distances.

Therefore, the block brake gear has been improved by making the braking pressure vary automatically in terms of the speed. At low speed, the pressure exerted at the brake cylinders remains limited to a minimum value which gives



(I) P Φ (v) = Adhesion.
(II) Q F (v) = Braking effort of block brake.
(III) = Braking effort of drum brake for V = 100 km. (62 miles) per hour.
(III') = Braking effort of drum brake for V = 40 km. (25 miles) per hour.

Note: Effort tangentiel = Tangential effort. — Adhérence = Adhesion.

Fig. 78.

a pressure on the brake blocks equal to 80 % of the weight, a value at which there is no danger of picking up the wheels. At high speed, the pressure can be much greater, corresponding, for example, to 180 % of the weight at a speed of 140 km. (87 miles) an hour, a value which, as the speed diminishes, falls to the value corresponding to that at which the wheels would be picked up at stopping.

The automatic variation of the braking pressure in terms of the speed is obtained by means of equipment employing centrifugal force, driven by one of the axles of the vehicle.

Messrs. JOURDAIN-MONNERET have applied an arrangement of this kind to the automatic brake fitted on the Franco-Belge railcars of the French Nord, and the WESTINGHOUSE Company have developed another arrangement in use on two Baudet-Donon-Roussel railcars on the P. O.-Midi Railways, and on a double Renault railcar of the French State Railways, which is also to be fitted to a number of railcars under construction.

Drum type brakes.

When the brake acts on a drum, the coefficient of friction between the brake lining and the drum is almost constant at all speeds. The factor P Φ therefore grows whilst QF remains practically constant (see figure 78) so that there is no fear of skidding at slow speeds.

Q can therefore be given the value that will ensure maximum braking at the highest possible vehicle speeds. If the maximum speed be V, Q can consequently be given such a value that

$$QF_{(V)} = P\Phi_V \qquad Q = P\frac{\Phi_V}{F_V}.$$

Figure 78 shows the curves of the retarding forces of the drum type brake for V = 40 (25 miles) and for V = 110 (68.3 miles). If these curves are compared with those when the block brake is used, it will be seen that when first braking the drum brake has the advantage over the block brake, and only below the speed value given by the intersection of the curves of the retarding forces does the block brake become better. It would appear, a priori, more interesting for a brake to have the greatest efficacy at high speed, and under reserve of the results of the devices for regulating the pressure of the brake in terms of the speed, described above, calculation and experience both show that the final advantage remains with the drum brake, both as regards length of the stopping distance and the stopping time. For the moment, its use is rather limited to direct acting brakes, automatic brakes being the most usual with the block brake type. However certain railways, such as the Alsace-Lorraine, already using the automatic drum type brake, and others such as the Hungarian Railways, intend to fit it to their new railcars.

If theoretically the drum brake is definitely to be preferred, practically speaking it still has the following drawbacks : It takes much room, whether the drums are placed between the wheels and soles, as the linings are awkward to renew, and it is very difficult to replace the drums, or when they are outside the wheels, the wheels having then to be of large diameter for the drums to come within the loading gauge.

The linings wear rapidly if they are not made of ample size in proportion to the actual weight of the railcar. Builders now use drums in special steel (chrome-molybdenum) and improved linings which have considerably increased the life of these brakes. Finally, if the distant control of the drum brake gets out of adjustment, there is danger of the wheels being skidded *at high speeds* (and not at low, as when block brakes are fitted). A vehicle which picks up its wheels at high speeds is much more dangerous than one which skids at slow speeds, because it would strike any obstacle with its full momentum. It should be noted, furthermore, that special precautions have to be taken to see that the sanding is instantaneous and operates before the brake acts so that the coefficient of adhesion is a maximum when there is danger of skidding.

* * *

As regards the method of transmitting the initial braking effort, fluid transmission is the most usual, at least when the drum brake is used. A few isolated applications are even found on railcars fitted with the automatic block brake, as for example the « Franco-Belge » railcar mentioned above.

Finally, the usual method of control is by a driver's valve in the case of the automatic brake, and a pedal when the direct brake is used.

II. *Emergency brake.*

An emergency brake distinct from the service brake is not fitted on all rail motor cars. In many instances, the service brake is used for emergency applications. Such application can be made by the driver, by the usual application device, or by the guard or passengers, by an alarm device, when the service brake is automatic.

The electro-magnetic rail brake is much used in France and Germany as a special emergency brake. The magnetic shoes of this brake are energised by

passing an electric current through them when applying the brake and this brings them in contact with the rails. It has the pecularity of being independent of the adhesion and can therefore give high retardation. It is therefore remarkable as an emergency brake and is the only one used on railcars.

Its repeated action, however, leaves blue marks on the rail, from which cracks rapidly develop; tests made by the French Railways show that the structure of the metal undergoes a transformation which makes the rail very brittle after a certain number of brake applications.

Moreover it has been found that induced currents are set up in the rails when the magnetic brake is applied; in the case of automatic signalling, these currents are capable of causing the track relays to be actuated untimely, and consequently interfere with the signalling. The question is being very carefully gone into by the engineers of the different French railways, and it is possible that certain alterations may be made in the present arrangement of the electro-magnetic brake.

III. *Standby brake.*

The standby brake is usually the hand brake, screw or lever operated, acting directly on the rigging of the service brake when fitted, or is quite independent when no such brake is fitted.

When the service brake is automatic, the standby brake is frequently a compressed air direct-acting brake which duplicates the former.

Some railcars are not fitted with any standby brake. In this case, the service brake is divided into sections, each acting on some of the braked wheels only, with independent control.

We saw that, when the compressed-air direct-action brake is fitted, the air is admitted to the brake cylinder directly without passing through a distributor. The driver himself regulates the quantity of air admitted into the cylinder and thereby varies the braking power as he wishes. He can as a rule apply the brake hard enough to pick up the wheels, this action varying with the speed.

When the automatic brake is fitted, the maximum pressure which can be obtained in the brake cylinder is constant, and is fixed. The maximum braking is therefore also constant and independent of the speed, and this is a valuable characteristic of the railcar, which is expressed in the form of the braking coeficient.

In the case of the block brake this braking coefficient is the ratio of the actual pressure on the blocks to the total weight of the vehicle. In Central Europe, it is usually 80 to 85 % of the tare, and 65 to 70 % of the loaded vehicle weight. In France it is generally much higher and is 100 to 105 % of the tare and 75 to 80 % of the loaded weight.

We can give no precise data on the brakes using drums, as these have been used almost solely with the direct acting brake up to the present.

* * *

CHAPTER VIII.

AUXILIARY APPARATUS.

By auxiliary apparatus we mean all plant used to produce the compressed air and electricity required on the railcar for the auxiliaries. We will deal more particularly with the following : air compressors, charging dynamos, accumulators, and starters.

Air compressors.

The air compressors used on rail motor cars are usually piston air pumps and are air-cooled. Their output differs from one type to another, as it is subor-

dinated to the size of the vehicle and to the number of trailers hauled. They supply the brake gear and other auxiliary equipment (sanders, screenwipers, and audible warning devices).

These compressors give from 125 to 1 400 litres (4.4 to 49 cu. feet) a minute. The pressure is 7 to 8 kgr./cm² (99.5 to 114 lb. per sq. inch).

In the case of railcars with mechanical transmission, the compressor is coupled direct to the diesel engine or mechanical transmission, and it is fitted with valves automatically regulating the pressure between two close limits, about 0.5 kgr. (7 lb. per sq. inch).

The Westinghouse Company has built belt-driven compressors which cut in as soon as the pressure drops below 6 kgr. (85.3 lb.), and cut out when it rises to 8 kgr. (114 lb. per sq. inch). The drive is by a triple belt of trapezoidal section of the Texrope type.

This arrangement considerably reduces the wear of the compressors.

On railcars with electric transmission, the compressors usually fitted are driven by special electric motors.

On some steam railcars working at very high pressure, a special compressor is used, driven by a small high-pressure steam engine (Reichsbahn).

Charging dynamos.

The first railcars were fitted with dynamos of the automobile type. It was soon realised that this equipment was quite inadequate to meet the heavy service required from a railcar. The charging dynamo, indeed, plays a very important part, as it has to maintain a large-capacity battery, the lighting, and frequently to feed the electro-valves of the gearboxes and the reversing gear, as well as of the electro-magnetic brakes.

The capacity of the dynamos, originally 500 watts, has been increased, on certain modern railcars, to 1 800 watts. The voltage is 24. Their characteristics have been improved to enable them to charge the batteries at the idling speed of the diesel engine, and this makes it easy for them to supply the necessary charging current for the accumulators.

As an example, a description of the E. V. R. dynamo and the Bosch dynamo is given below.

— *E. V. R. dynamo.* — The E. V. R. dy-

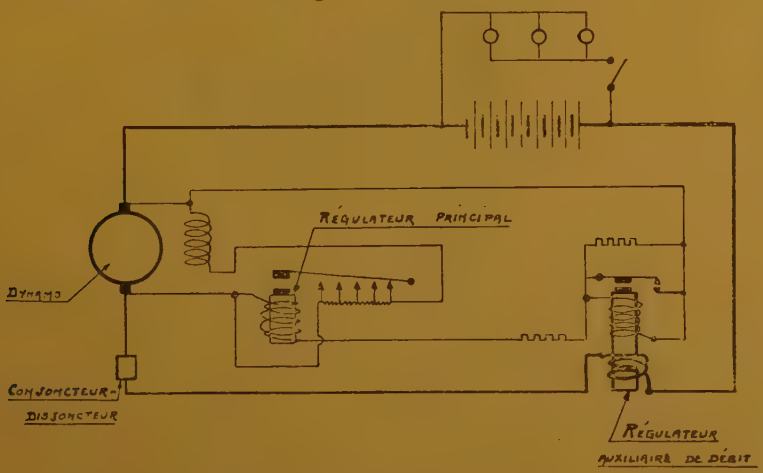


Fig. 79. — The E. V. R. equipment. — Principle of design.

Explanation of French terms:
Régulateur principal = main regulator. — Conjoncteur-disjoncteur = self-closing circuit breaker.
Régulateur auxiliaire de débit = auxiliary output regulator.

namo, a diagram of which is given in figure 79, is fitted with a main regulator and an auxiliary regulator.

The combination of these two regulators makes it possible to charge the batteries at a practically constant intensity during two thirds of the charging time, and after that at constant voltage.

This gives the advantages of constant voltage and of constant amperage without their drawbacks.

This combination is of value when the service covered by the railcar includes frequent stops and therefore involves the diesel engine being frequently restarted, which quickly discharges the battery.

The main regulator is of the comb type; it inserts varying resistances into the excitation circuit of the generator.

The output regulator is a trembler regulator, the contacts of which only cut under a current of some tenths of an ampere. Its electro-magnet is fitted with a main winding through which the total current generated by the dynamo passes, and an auxiliary winding with thin wire.

Thanks to this auxiliary regulator, the output cannot exceed the intensity for which it is adjusted; it is even possible to cut out one or two elements of the battery without the current exceeding its normal value. The most important advantage of this arrangement is that the battery can be charged up quickly and this is equivalent to making better use of the dynamo capacity.

Moreover, with this arrangement a battery of accumulators can be charged with two dynamos in parallel, a feature of particular value for two-engined railcars with mechanical transmission.

— *Bosch dynamo.* — The Bosch dynamo has a six-pole field magnet system in shunt with the armature, through a voltage and amperage regulator.

The voltage regulation is obtained by a double regulator; the excitation is obtained by two distinct windings, each circuit passing through a regulator. The voltage is regulated by inserting an additional resistance in the excitation circuit by a pair of contacts (fig. 80).

This additional resistance is wound on the core of the trembler coil and

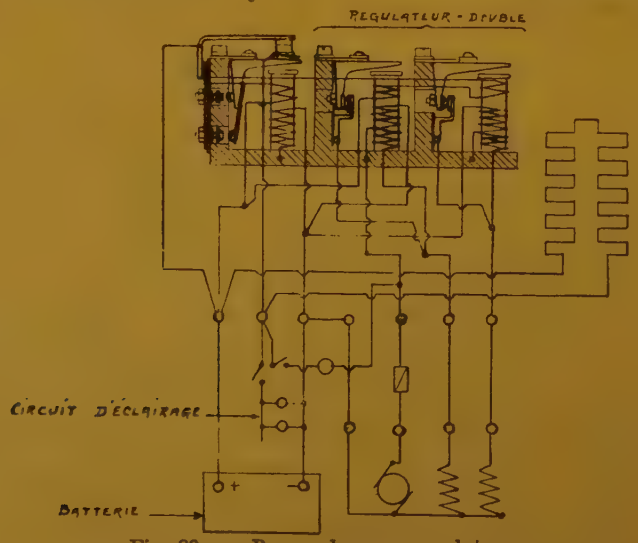


Fig. 80. — Bosch dynamo regulator.

Note : Régulateur double = double regulator. — Circuit d'éclairage = lighting circuit. — Batterie = accumulators.

makes and breaks the contact at high frequencies.

This core also carries a voltage and amperage winding, through which the total current generated by the dynamo flows.

This regulator gives a charging characteristic independent of the speed of rotation within very wide limits : 1 000 to 4 000 r.p.m.

On railcars with electric drive, the problem of charging the batteries is much simpler.

If the auxiliary generator helps to regulate the electrical equipment, the battery is charged at constant voltage through a resistance; the excitation is corrected to suit the different working conditions of the diesel engine.

In other cases, the characteristics of the auxiliary generator are suitable for charging the accumulators and, as in the previous case, the excitation is adjusted to suit the working conditions of the diesel engine. These adjustments are made either by contactors, or directly by the railcar driver.

Accumulators.

Railcars with internal-combustion engines are fitted with a battery of accumulators, this being one of the essential fittings. Indeed, the battery is used to start up the diesel engine and to light the vehicle. On railcars with electric transmission, the voltage of the auxiliaries is relatively high (96 or 115 volts), so the battery problem is easily solved. The engine is started by the main generator and the current intensity does not exceed the amount compatible with keeping the plates in good order.

The problem is quite a different one when mechanical drive is used; the 24-volt tension generally adopted involves the use of very-high-capacity batteries such as 400 to 500 ampere-hours. The starting current strength for the diesel engines reaches 2 400 amperes, so that these batteries work at 5 to 6 times their nominal capacity.

Up to now, lead accumulator plates have been used and also alkaline batteries, the advantages and drawbacks of these types being well known. The alkaline batteries appear to be preferred by many railways.

Starters.

The diesel engines are in most cases started electrically; for this purpose series-excitation electric starters, fitted with suitable equipment, are used to engage without shock the starter pinion with the toothed ring and disengage it as soon as the engine fires; the release should occur automatically and with precision, as the armature would otherwise be driven by the diesel, and its rotational speed could break it down.

The power of the starters depends on the size of the engines, the number of cylinders and their design. As a rule, starters of 6 to 15 H.P. are used, and sometimes several starters are coupled in parallel under the same toothed wheel.

Scintilla starters. — The Scintilla starter has a series winding and an auxiliary winding. The latter is in series with the rotor, and rotates the starter in the opposite direction to normal running and at reduced speed.

In addition, an electro-magnet is mounted on the armature spindle, and causes the pinion to engage with the toothed wheel (fig. 81).

As soon as the pinion is engaged, a contactor allows the current to flow through the principal windings of the starter which begins to revolve in the normal direction and starts the diesel engine. The combined action of the field winding and the principal winding limits the speed of the starter.

As soon as the diesel engine starts the current must be cut off. A roller coupling between the spindle and the pinion prevents the motor from driving the

starter at too high a speed once it is started.

Bosch starter with sliding armature. — The Bosch starter includes an armature which, when at rest, is out of centre relatively to the poles. The induction system consists of a series winding, a shunt winding, and an auxiliary winding. The engagement of the pinion with the toothed wheel of the diesel engine is obtained by moving the armature. The latter, when moved, only rotates at low speed, which makes it easy to engage the teeth of the pinion with the toothed ring on the motor.

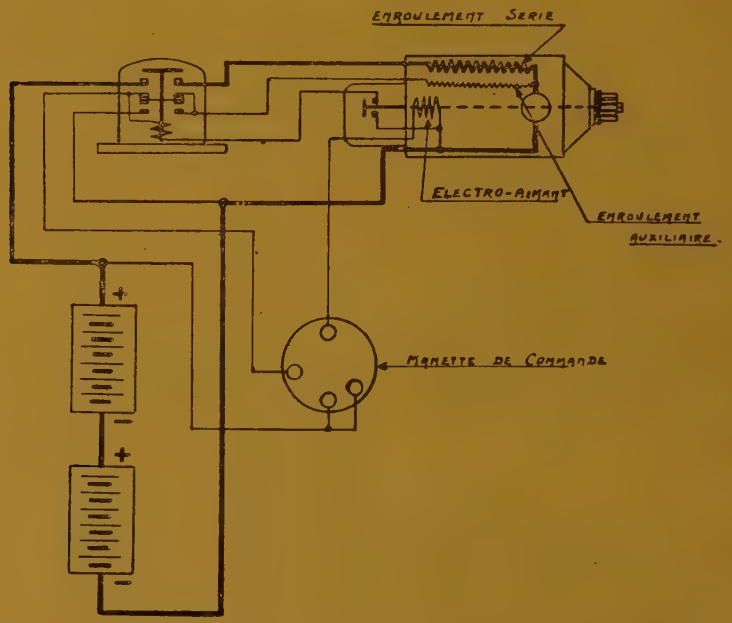


Fig. 81. — The Scintilla starter. — Principle of design.

Note: Enroulement série = series winding. — Electro-aimant = electro-magnet. — Enroulement auxiliaire = auxiliary winding. — Manette de commande = control handle.

When the starter pinion and the toothed wheel are well in mesh, the starter itself automatically begins to revolve and develop the full power required to start the engine.

As soon as the diesel engine is running and the speed of the toothed ring exceeds the speed of the starter, a multiplate clutch at once cuts off the connection between the starter pinion and the armature, thereby making sure that the latter will not revolve at a dangerous speed. As soon as there is no pressure on the pinion, the armature of the starter returns to its normal position, as the shunt and auxiliary windings are not sufficient to overcome the action of the check spring.

* * *

CHAPTER IX.

STEAM RAILCARS.

Steam railcars, so widely used in England, are only found in Europe in small numbers, which can be divided into three groups :

1 — Railcars consisting of a small steam locomotive, of an improved type, and coupled to a carriage body (Esslingen railcars for Turkey, fig. 82);

2 — Railcars fitted with a boiler with a free exhaust and having a pressure of about 20 hpz. (300 lb. per sq. inch) (Sentinel railcars of the Belgian National Railways Company and of the French Nord, and Birmingham railcar of the Belgian National Railways Company);

3 — Railcars fitted with a boiler of the condensing type, boiler pressure of 70 to 80 hpz. (1 015 to 1 160 lb. per sq. inch) (Henschell railcars with Doble boiler, of the Reichsbahn).

Fig. 82. — ESSLINGEN railcar for Turkey.

Steam railcars have certain advantages :

— Easy to handle;

— Good starting and great acccelerration, as at starting the engine can develop the maximum power allowed by the adhesion;

— Elimination of certain delicate parts : such as gear boxes, clutches, reverse gear, which makes it possible to provide sturdy and easily maintained motions.

The requirements of the railways as regards steam railcars appear to be the following :

1 — Absolutely automatic boiler feed and control, so that the railcar can be driven by one man.

Railcars with the Doble type of boiler are entirely suitable for automatic running and for distant control by a single man, whereas the other railcars require a driver and a fireman; the French Nord, however, has just put into service a Sentinel railcar with a Woolnough oil-fired boiler at a pressure of 23 hpz.

(333 lb. per sq. inch), which is normally driven by one man.

The builders of steam railcars requiring two men point out that the cost of the fireman is less than the additional maintenance costs of the diesel railcar; Belgian experience would appear to confirm this point of view, on which, however, it is necessary to reserve a definite opinion.

2 — High-pressure boiler with condensing, which has a much greater efficiency, so that the supplies of water and fuel give sufficient radius of action.

Description of certain parts of railcars.

Woolnough boiler (French Nord railcars, fig. 83).

The Woolnough boiler is built up of three drums and water tubes giving superheated steam at 400° C. (752° F.) at a pressure of 23 hpz. (333 lb.)

Two water drums are arranged along each side of the firebox and are connected, by two groups of tubes sharply inclined and slightly curved inwards, to the upper drum placed on the centre line above the firebox.

Fig. 83. — Woolnough boiler.

The boiler is fitted for automatic firing and has a feed water regulator; the burner works with a steam jet spray at low pressure. Valves regulate the flow of steam and oil fed to the burner.

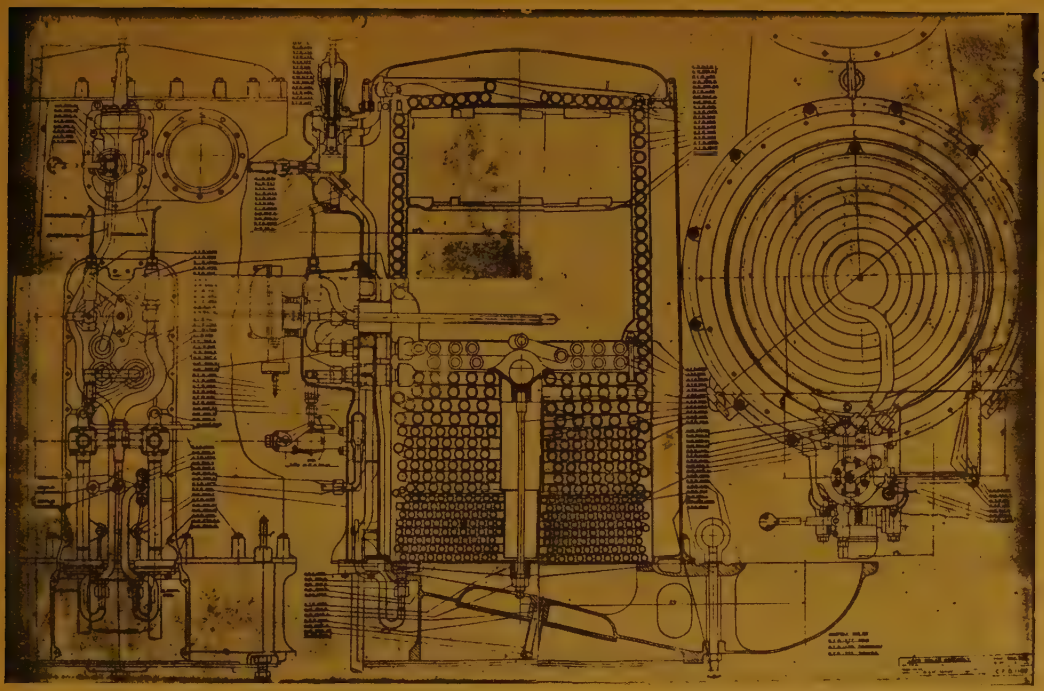


Fig. 84. — DOBLE boiler.

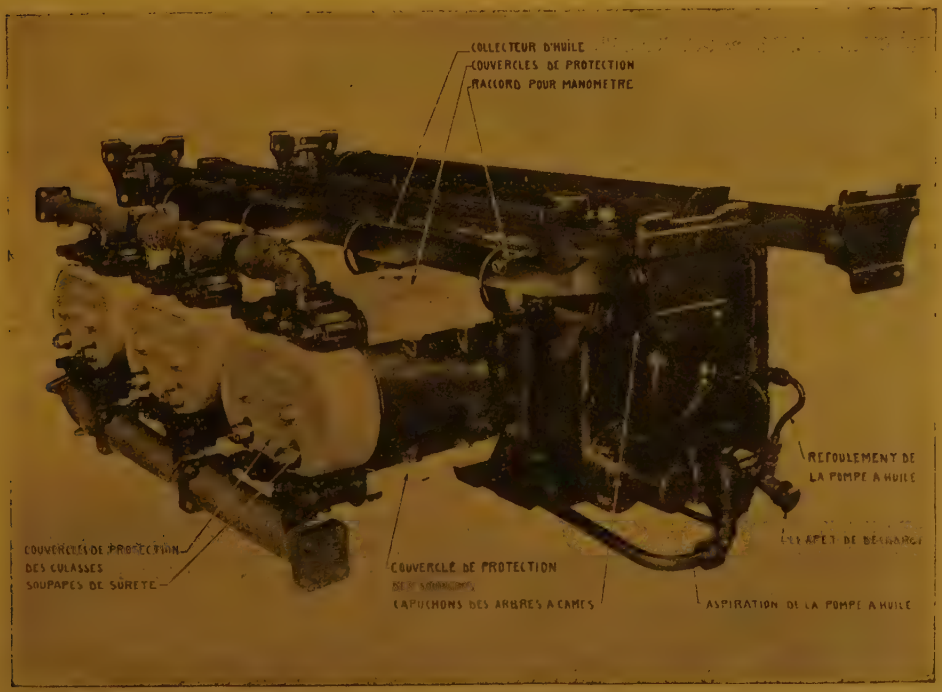


Fig. 85. — SENTINEL engine.

Explanation of French terms:

Collecteur d'huile = Oil catcher. — Raccord pour manomètre = Nipple for pressure gauge. — Couvercles de protection des culasses = Cylinder head protecting covers. — Soupapes de sûreté = Safety valves. — Couvercle de protection des soupapes = Valve protecting cover. — Capuchons des arbres à cames = Cam shaft caps. — Aspiration de la pompe à huile = Oil pump sucking pipe. — Clapet de décharge = Relief valve. — Refoulement de la pompe à huile = Oil pump delivery pipe.

Doble boiler (Reichsbahn railcar fig. 84).

The Doble boiler is a monotubular high-pressure boiler giving superheated steam at 400° C. (752° F.) at a pressure of 70 to 80 hpz. (1 015 to 1 160 lb. per sq. inch).

This boiler is heated by a special burner, and works entirely automatically; the water fed to the boiler, and the fuel to the burner, are regulated by the combined action of a thermostat and a pressure gauge with electric contactors, which open or close the circuit of the electro-valves acting either on the feed pump or on the burner.

Engines.

The engines used are of different types but are all geared down about 3 to 1, unlike the ordinary locomotives in which the connecting rods drive the axles directly. This arrangement has made it possible to reduce the dimensions and weight of the engine.

With a pressure of 20 hpz. (300 lb. per sq. inch) the engines are usually simple-expansion with poppet valve gear, and are single acting (fig. 85) (Sentinel railcars of the Belgian National Railways Company and the French Nord). With the increased boiler pressure, the present tendency is to use compound engines with two double-acting cylinders and Stephenson valve gear.

* * *

CHAPTER X.

UNDERFRAME AND BODY.

I. — Metal underframe and wooden body.

Most of the railways only used this type of construction for their older railcars, which now only represent a small proportion of the stock (about 10 %). This method of construction is generally no longer considered for new constructions.

A few railways only recently directed their attention to all-metal construction. Thus, the Danish State Railways own 65 railcars with wooden bodies out of the 76 vehicles in service, and the Czechoslovak Railways have 338 railcars with wooden bodies out of 390 in service; the latter Administration, moreover, intends to retain the wooden body for light railcars.

The Finnish State Railways use wood exclusively for body construction and are continuing this practice in the case of the 4 units now ordered, probably because of the extensive supplies of wood in that country.

The Piedmontese Tramway Company are following the same practice, and have never considered any other form of construction.

* * *

II. — All-metal underframe and body.

1. Resistance of the combined underframe-body unit to the stresses to which it is subjected.

The problem as regards the strength of the vehicle to resist the various forces involves an investigation of the following main points :

a) *Resistance to the usual service stresses.*

The combined underframe-and-body unit should resist, without any appreciable deformation, the bending stresses to which it is subjected by the vertical loads it carries (dead weight, passengers, luggage), the dynamic bending and torsional stresses due to these loads when the vehicle passes over the various unequalities in the track being naturally taken into account.

The strength to resist the vertical loads and the dynamic bending and torsional stresses resulting therefrom is checked empirically in ordinary service, but can be controlled more accurately and more scientifically in the Works, as for example in the following way :

The whole unit — frame and body — being assembled, is carried on supports in line with the actual bearing points of the vehicle in service, and loaded in a given way and subsequently unloaded, after the maximum deflection has been measured.

The same test, with one of the supports removed and the maximum deflection measured, supplies information on the resistance to torsion.

In no case should any permanent deformation be found when the load is removed.

Table IV summarises the results of

Table IV.

Vehicle.	*Test.*	*Results.*
Renault. Design in which the body sides transmit the forces.	Uniform load of 34 t. (33.46 Engl. tons) representing : Weight of the body + 2.5 times the useful load.	Maximum deflection 25 mm. (1 inch). No permanent set.
Franco-Belge. (Tubular girder type).	Torsion of the body when supported at 3 points.	The 4th point dropped 6 mm. (1/4 inch). No permanent set.
Compagnie générale de construction. (Rigid frame and light body type).	Flexion, then torsion of the bar frame loaded uniformly and carried on 4 supports at the ends of the sole bars.	No permanent set.
	Same test after erecting body on the frame.	Much smaller elastic deformations.
8-wheeled Charentaises. (tubular girder type, in aluminium).	1. Body supported at 8 points corresponding to the axles. Weight of the body + 2 times normal load (uniformly distributed).	At the centre the amplitude of the oscillations was ± 1 mm. (3/64 inch).
	20 men in the railcar subjected the vehicle to a rhythmic bending movement.	No permanent set.
	2. Body carried on the two headstocks. Weight of the body + 1.5 times the normal load acting inside the supports.	Deflection at middle point 8 mm. (5/16 inch). No permanent set.
Decauville. (tubular girder type).	1) Body carried on its normal supports, and weight made up by 200 people inside the vehicle.	No deflection.
	2) Same arrangement, but the 200 men making most disorderly movements.	Deflection of a few millimetres in the case of rhythmic movements.

tests carried out on a number of French railcars.

b) *Resistance to exceptional stresses.*

In the case of collision, the whole unit should be able to absorb to the maximum possible extent the inertia forces of the moving masses without such deformation occurring as might hurt the passengers.

This can be obtained in two absolutely distinct ways : either by designing a rigid underframe providing the resistance factor of itself, or by designing a very rigid underframe-body unit forming a tubular girder.

— *Rigid underframe providing the resistance factor of itself.* — The body assembled with this frame is then simply a shelter to carry the passengers.

In this form of construction the body can, however, be rigidly connected to the underframe and take part in stiffening up the whole. It must then be sufficiently rigid not to get out of line through the frame moving in service.

The body can also be attached elastically to the underframe. In this case, it plays no part in strengthening the unit. The body of the Bugatti railcar, in particular, is connected to the underframe in a special way, i. e. by means of spherical cups secured to the longitudinals on which rest the spherical pivots carrying the body, indiarubber being inserted in between (fig. 86).

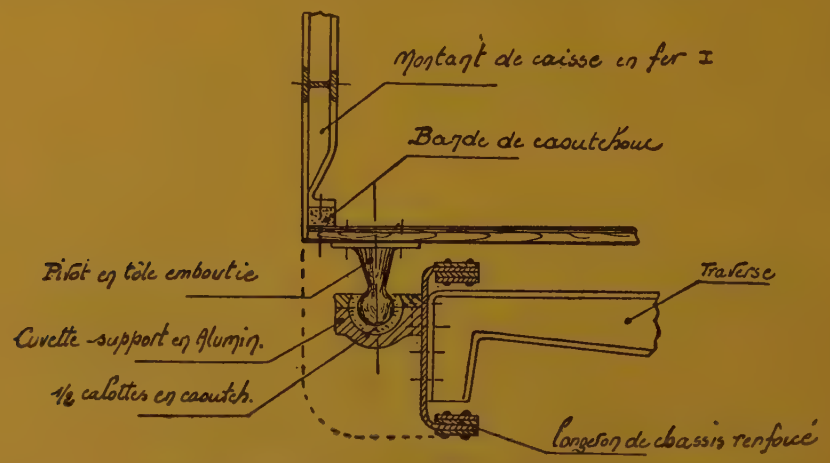


Fig. 86. — Bugatti railcar. Elastic connection between underframe and body.

Explanation of French terms:

Montant de caisse en fer I = Body pillar of rolled-steel I section. — Bande de caoutchouc = Strip of rubber. — Pivot en tôle emboutie = Pressed-steel pivot. — Cuvette-support en aluminium = Aluminium bearing cup. — 1/2 calotte en caoutchouc = Half cup-shaped rubber packing. — Traverse = Cross bearer. — Longeron de châssis renforcé = Strengthened sole bar.

The desire to lighten the body has even led in the case of the 24-seater Micheline to a design not having any body properly speaking, the underframe and the body framing forming one unit assembled by riveting and welding, the body being formed by a covering in thin metal sheeting lined inside with imitation leather, fastened to wood blocks secured to the body frame members.

This extra-light type of construction, due to the limited loads pneumatic tyres can carry, has however been abandoned

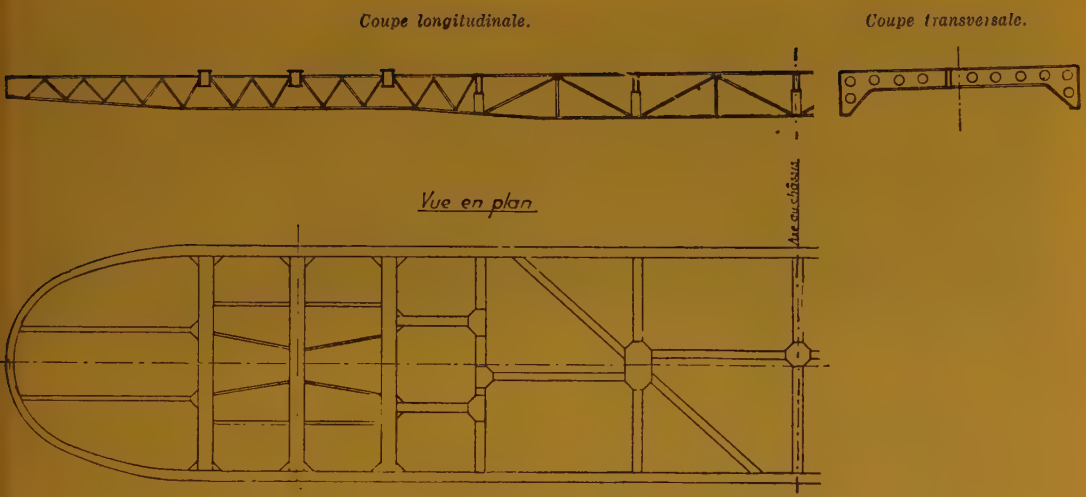


Fig. 87. — Underframe of the 36 and 56-seater MICHELINES.

Note: Coupe longitudinale = longitudinal section. — Coupe transversale = cross section. — Vue en plan = plan view. — Axe du châssis = centre line of underframe.

in the case of the Micheline railcars with 36 and 56 seats, these having a rigid underframe with a high moment of inertia (fig. 87), the light body being bolted to it and treated wood being inserted between the two.

— *Tubular girder.* — With this design, the modern principles regarding all-metal passenger stock construction are applied; the strength necessary to withstand the shocks in case of collision is obtained by a very rigid underframe-body unit including very strong roof members firmly braced to the underframe by the two body sides. The whole unit, completed by relatively thick metal sheeting (about 4 mm. = 5/32 inch), in all-metal railcars forms what is known as the « tubular girder ».

The description of « tubular girder » is, it must be pointed out, only partly true, as the ideal tube has never been built in railway stock, because in line with the bogies it is necessary to cut the tube.

However, the behaviour of this stock in case of collision has shown that the design was very satisfactory in the way of protecting the passengers, and this justifies the tendency of certain builders to follow this design.

This solution of the problem can, however, be obtained in practice in different ways :

— either, an endeavour is made to design a unit all the parts of which (side, roof and floor members) play their part in the general strength (e.g. the FRANCO-BELGE rail motor trains);

— or, only the sides form the main resistance members, in which case they can simply be connected by the roof and the floor (e.g. the RENAULT railcars);

— or, contrariwise, the roof and the floor can be carefully designed from the point of view of strength and rigidity, the sides then simply acting as connections between these two parts (e.g. the ACIÉRIES DU NORD railcars);

It is necessary to point out, nonetheless, that railcars, by nature, must be lighter than up-to-date all-metal coaches,

Fig. 88. — Ford railcar (Sarre).

on account of the greater power they would otherwise need. These vehicles are therefore necessarily a little less rigid.

For instance, the outside sheeting, of steel or aluminium alloy, is so thin that in most cases it does not add materially to the strength (Maximum thickness of plates : 2 to 2.5 mm. = 5/64 to 3/32 inch).

As a rule, the ends are not specially strengthened. On the contrary, the builder expects, in some cases, the non-reinforced ends of the body to absorb, by deformation, the impact of the moving masses and so prevent any deformation of the underframe properly speaking, i.e. that part which carries the passenger compartment. For example, the Decauville railcars (French Nord), Ford (Sarre) (fig. 88), and Austro-Daimler (Austria) are built in such a way that on telescoping the engines themselves would absorb the greater part of the shock; the Czechoslovak 4-wheeled railcars are provided with strongly-built platforms on which passengers are not allowed to stand.

2. Precautions taken against telescoping or collisions.

When a train comes into collision, every coach making it up must absorb, besides the shock due to the obstacle met with, the impact from all the vehicles which are coupled up behind it; railway carriages must be specially designed to resist telescoping and it may be said that modern all-metal coaches meet the above requirements as far as possible.

The case of the railcar is rather different, as most often it is a vehicle intended to run by itself.

It is quite legitimate, therefore, independently of the question of weight, and consequently the traction cost of these vehicles, to accept the tubular girder type of lighter construction for such vehicles.

Figures 89 and 90 show a Renault railcar of rigid construction, after it had been run into and driven back by a locomotive, in a depot, against two wagons laden with rails, and then against a buffer. Only the ends have suffered, the passenger compartment being left intact.

Then too, a relatively light construction has the advantage of lower impact forces in case of collision, so that the damage done is not necessarily as serious as in the case of heavier stock.

Figure 91 shows a Micheline which had collided with a road motor car on the French State Railways.

This light Micheline, travelling at 92 km. (57 miles) an hour, ran into a road

motor car moving over a level crossing. The motor car was hurled twenty yards away, and the railcar came off the rails, struck an obstacle and turned over, but only suffered relatively little damage from the collision and its after results. The passengers were only slightly bruised.

3. Buffing and draw gear.

Most builders have provided their railcars with buffing and draw gear.

a) *Buffing gear.*

A lighter type of railway buffer is usually resorted to.

Certain French builders, however, to save weight in the case of railcars intended to run alone, have provided simple shock absorbers, of little weight, consisting of small buffers or merely bumper plates.

b) *Draw gear.*

These parts are sometimes of the ordinary screw coupling type, but lighter.

The builders, however, in view of the little use made of the couplings on ordinary rail motor cars, are satisfied in most cases with providing a simple eye bolt on each headstock. This can be used in connection with a special draw bar which fits on the ordinary draw hook, and is usually stowed in the guard's locker or under the body.

c) *Automatic couplings.*

Automatic couplings have found a certain number of applications on railcars. Thus, the *Scharfenberg* coupling is used in Germany, Austria, Holland and Hungary — and the *Willison* coupling in France.

To couple up a railcar with an ordinary vehicle in case of accident, however, requires a special device such as the lightened *Willison* transition coupling (fig. 92).

Fig. 89. — A telescoped Renault railcar (France).

Fig. 90. — End of the RENAULT railcar, nearest the locomotive, after telescoping.

4. Description of some couplings used on multiple-unit railcars.

a) *Vehicles forming articulated units, permanently coupled together.*

We give hereafter a description of the couplings designed for the following railcars : S. O. M. U. A. (French State); Schnelltriebwagen (Reichsbahn); Double Renault (French State); La Brugeoise (Belgium); Dutch triplet sets; double Bugatti (P. L. M., France).

— *S. O. M. U. A. (fig. 93) — 2 articulated units on 3 axles.* — This six-wheeled rail motor car is formed of a four-wheeled power unit and a trailer. The outer end of the latter is carried on a third pair of wheels, and the inner end on the underframe of the driving unit. For this purpose the underframe of the power unit is fitted with a cast-steel hemispherical cup which, with the hemispherical pivot on the frame of the trailer, forms a central articulated cou-

Fig. 91. — MICHELIN railcar (France), after coming into collision with a road motor car and a fixed obstacle.

pling. A bolt keeps the two parts of the coupling permanently together.

The rolling movements of the trailer are prevented by two spring shock absorbers placed on both sides of the knuckle joint. Each of the trailer sole bars rests on the piston head of one of these shock absorbers, friction blocks being inserted, which allows of easy curve negotiation.

The trailer is either pulled or pushed, according to the direction in which the vehicle is running, the resulting effort being transmitted by the articulated coupling itself.

— *Schnelltriebwagen, Double Renault twin car, La Brugeoise — 2 articulated units carried on 3 bogies (fig. 94).*

The underframe of each body carries at its inner end a spherical pin; the pin of one of the bodies fits in a spherical cup secured to the bogie and that of the second frame fits in a cup provided in the top of the first one.

The lateral stability of the two bodies is obtained by two semi-spherical buffers with large rubbing surfaces, fitted with double shock-absorber springs.

— *Triplet cars of the Netherlands Railways — 3 articulated units on 4 bogies.* — Each intermediate bogie includes two separate supports close to each other, on both sides of the centre pair of wheels, on the longitudinal centre line of the vehicle. The adjacent end of the two bodies carried by the bogie is articulated on the nearest centre support.

— *Bugatti twins — 2 units carried on 4 bogies (fig. 95).* — The underframes

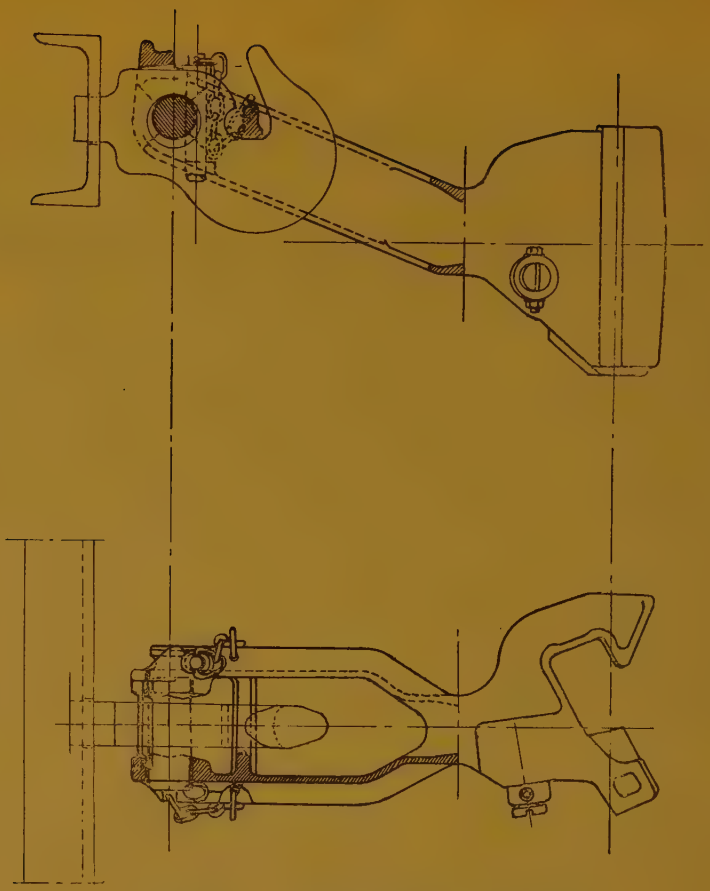


Fig. 92. — WILLISON transition coupling.

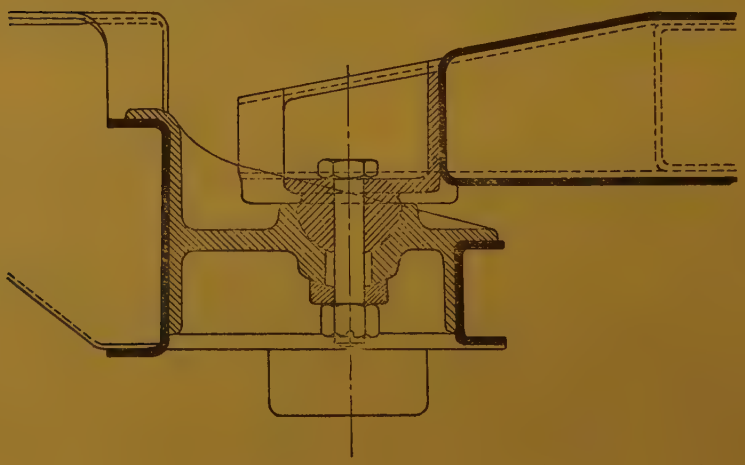


Fig. 93. — Coupling between the two units of the S. O. M. U. A. railcar.

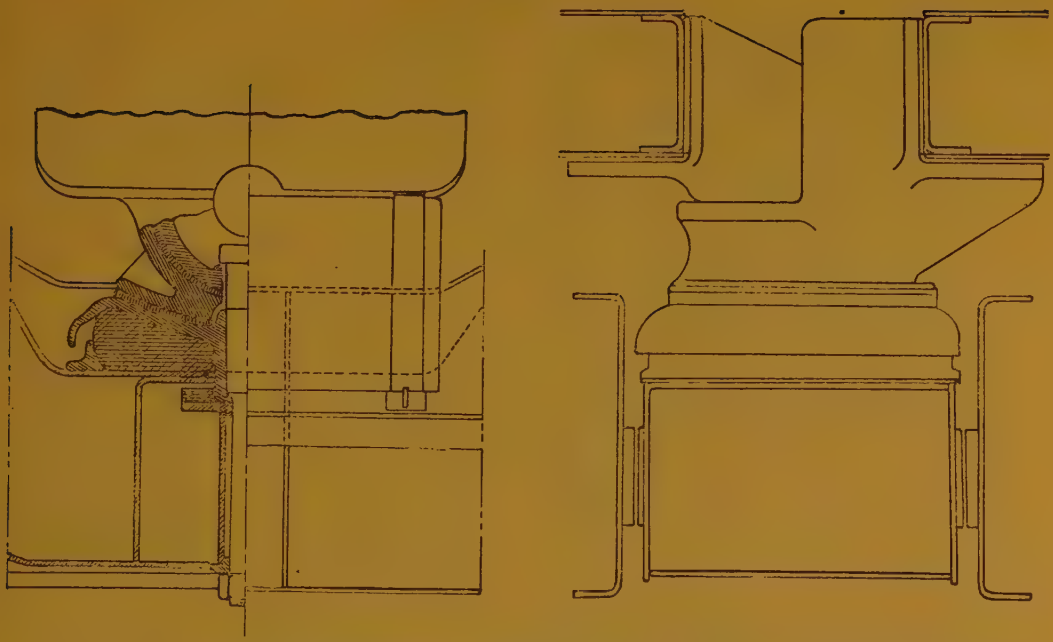
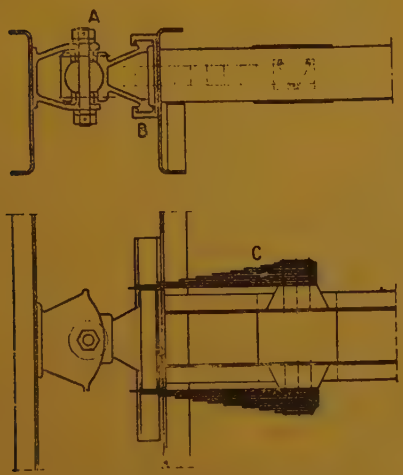


Fig. 94. — Double spherical bearing on which the bodies are carried on the middle bogie (Schnelltriebwagen, Renault twin, and La Brugeoise).



A = Pin with spherical knuckle.
B = Slide.
C = Centering spring.

Fig. 95. — Spherical coupling between the two units of the Bugatti railcar (France : Paris-Lyons-Mediterranean).

of the two bodies are connected by an articulation with knuckle pin and guide centered by two laminated springs.

b) *Railcars which can be worked either as a single unit or coupled to a trailer.* — There are only a relatively small number of railcars of that kind.

A description will be given of a coupling specially designed for the Bugatti railcars with trailers, which are now on trial on the French State Railways, and of the coupling used on the Franco-Belge railcars in use on the Nord (France).

— *Bugatti.* — This is a « tramway » type of coupling; it is not automatic, and provides a combined buffing and draw gear.

So far the running tests appear to be satisfactory. It must be added that, by using a special pole, the man coupling

up the units can guide the draw bar into position without getting in between the vehicle and its trailer.

Franco-Belge. — As each part of the vehicle is independent as regards running, the only problem to be solved was that of the coupling, which, in this case, is a Willison central coupler, completed by 2 non-conjugated buffers.

One of the buffers has been partly lined with ferodo to brake the relative movements of the two adjacent bodies when passing over bad spots in the track, without interfering in any way with curve negotiation, ferodo being applied only at the centre of the buffer.

III. — Materials used and methods of construction.

1. General.

So far most builders have preferred ordinary steel to high-tensile steels. The latter have appeared on the market at a relatively recent date, and may be said to be still in the trial period in connection with railway rolling stock.

Properly so called rustless steels have not been used in Europe, with one exception; the Societa italiana per le Strade ferrata de la Mediterraneo uses a rustless steel assembled by the *Shotweld* process of the Budd Mfg. Co.

As a rule, the use of aluminium and its alloys has been limited to body fittings as castings, and especially for inside or outside lining sheeting, either bent, curved or pressed. The Entreprises Industrielles Charentaises, in France, however, have built the whole of the underframe and body framing in duralumin rolled sections and aluminium sheet.

In certain cases, the use of certain materials is not possible or prohibited for other than technical reasons.

The Ganz Works in Hungary, for example, have had to give up the use of light alloys owing to importation difficulties.

As already mentioned, the Finnish State Railways probably use wood exclusively in body building, owing to the abundance of this material in that country.

2. Materials in current use.

a) *Steels.*

Ordinary carbon steels.

These steels, the usual qualities of which are semi-hard to mild, are used in all ordinary commercial forms : rolled sections, plates or pressings. Their low price and the well known methods of using them, have led many builders to prefer them for the main members.

In France, there is a definite tendency to use semi-hard open-hearth steel very carefully manufactured.

Special high-tensile steels.

Table V gives the main characteristics of the special steels most used and their principal applications.

Colum 5 gives, for two of the steels in question, a new characteristic known as the « dynamic elastic limit », from which it is possible to ascertain the resistance of the metal to alternated stresses at high frequency : the figures given have been obtained by means of a recent special machine, built by Messrs. Schenck, of Darmstadt, on test plates cut from the steel being tested.

b) *Light alloys.*

The light metals used are all aluminium alloys :

Aluminium :

Specific gravity : 2.6.

Characteristic of the metal :

Tensile strength = 11 kgr./mm² (7.0 Engl. tons per sq. inch). — Elongation

TABLE V.

SPECIAL STEELS USED IN THE CONSTRUCTION OF RAILCAR UNDERFRAMES AND BODIES.

Class of steel.	Tensile strength. Kg^r/mm^2 (*Engl. tons per sq. inch*)	Elongation. %	Elastic limit. Kg^r/mm^2 (*Engl. tons per sq. inch*)	Dynamic elastic limit. Alternated bending. Kg^r/mm^2 (*Engl. tons per sq. inch*)	Used for	Parts assembled by	Types of railcar.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Chrome-nickel steel	50/55 (*31.7/34.9*)	24	38/40 (*24.1/25.4*)	30 (*19.1*)	Body bolsters. Bogie sole bars and bolsters.	Electric welding and riveting.	FRANCO-BELGE. (French Nord).
Chrome-molybdenum steel . .	75 (*47.6*)	13	58 (*36.8*)	...	Frame and body throughout. (Outside sheeting up to bottom of side lights.)	Electric-arc welding.	DECAUVILLE. (French Nord).
Chrome steel . .	50/60 (*31.7/38.1*)	...	...	...	Underframe and body framing.	Welding (and occasionally riveting).	GANZ. (Hungary).
Chrome-copper steel	54/64 (*34.3/40.6*)	18/20	36 (*22.9*)	25/26 (*15.9/16.5*)	Underframe. Body.	Arc or spot welding.	COMPAGNIE FRANÇAISE. (Paris-Lyons-Mediterranean, France). DE DIETRICH. (Alsace-Lorraine Railways).

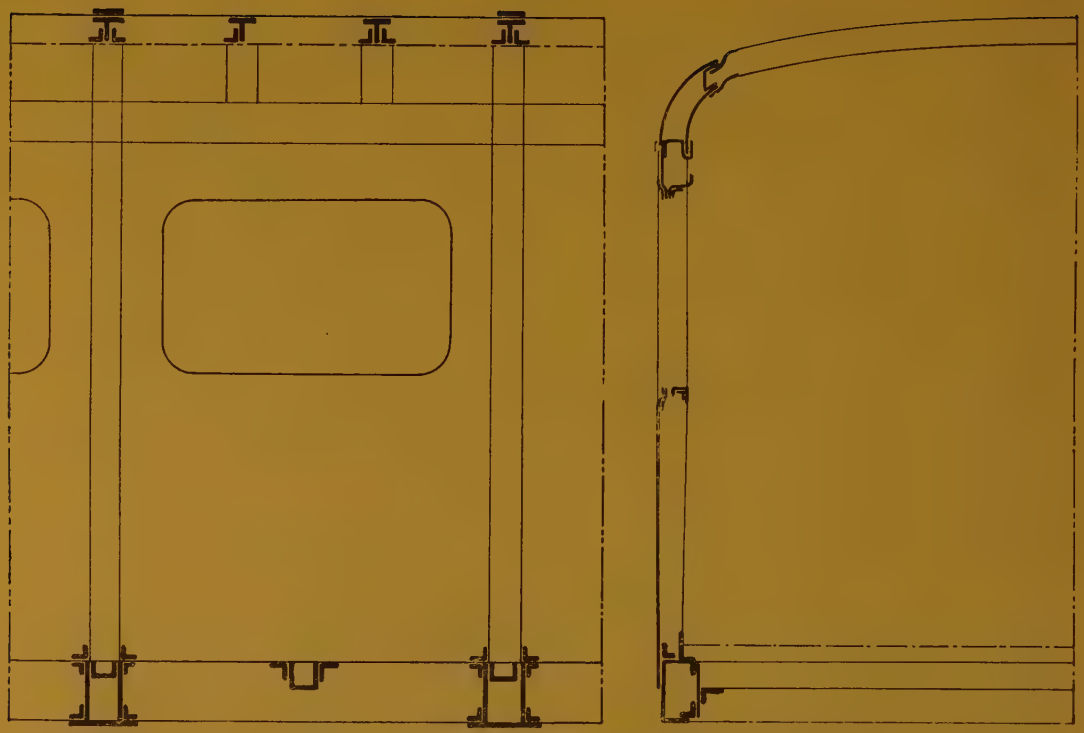


Fig. 96. — Railcar built by the Entreprises Industrielles Charentaises (French State). Framing made of light alloy.

= 40 %. — Elastic limit = 5 kgr./mm² (3.17 Engl. tons per sq. inch).

Pure aluminium is never used in parts subject to stress, but is most often used for the interior lining, ceiling, counter floor, the petticoat covering the running gear, and sometimes the roof itself.

Duralumin :

Characteristics of the metal :
Treated and aged.
Tensile strength = 38/42 kgr./mm² (24.12/26.67 Engl. tons per sq. inch). — Elongation = 16 to 24 %. — Elastic limit = 25 to 30 kgr./mm² (15.87 to 19.05 Engl. tons per sq. inch).

Duralumin is the light alloy most commonly used. It is used for all linings which, whilst not increasing the weight of the vehicle, are likely to undergo shocks, or wear, such as floors in luggage compartments, or the driver's compartments of railcars. For the same reasons, many builders have preferred to use aluminium for the outside body panelling or the roof.

The rail motor cars built in France by the Entreprises Industrielles Charentaises, mentioned above, consist of (cf. fig. 96) an underframe and a body built entirely of duralumin for the parts subject to stress or wear, with aluminium sheeting for non stressed parts of the vehicle.

Another interesting application of duralumin has been in the 24-seater Michelines.

Other alloys.

Other light alloys of various compositions are on the market. Their charac-

teristics and their prices enable them as a rule to be classed between duralumin and aluminium.

The wide use of aluminium and its alloys other than in the frame enables 2 to 3 tons to be saved on a rail motor car about 20 m. (66 feet) long.

c) *Non-metallic materials.*

With the exception of wood of which the body is wholly or partly made, the majority of non-metallic materials used are linings to insulate the vehicles or make them silent, and they are dealt with in a special chapter. Other materials are used to furnish or decorate the interior of the rail motor cars.

3. Design and method of making the various parts.

Cast parts are rarely used except as interior fittings (luggage-racks, door handles, etc.).

However, an example of the use of a cast part as an essential element of the structure is seen in the railcars built by the Aciéries du Nord, in France, with a body bolster in cast steel over the bogie centre pin.

Another example is to be found in certain Belgian railcars in which the ends of the underframe are of cast steel.

The usual rolled sections used in metal construction are being given up more and more as leading to excessive weight relatively to the strength obtained.

Most of the framing and the linings are pressings from plates. As, however, presswork involves special and expensive plant, a large number of pressings must be made to meet the initial expenditure. Consequently, many builders prefer to use bent plates, except when the complicated forms of certain end plates, for example, justify the necessary press tools for a few parts (see fig. 97, the framing of a Renault rail motor car).

Fig. 97. — Body framing of Renault railcar.

An interesting example of the use of tubes is to be seen in the body framing of the AUSTRO-DAIMLER fast rail motor cars on the Austrian Federal Railways (see fig. 98).

The body framing of the Dutch triplets is another example of a particular form of construction using tubes : the underframe and the body consist of tubes of the Mannesmann type in 0.25 % copper bearing steel, of circular or rectangular section, obtained either by

Fig. 98. — Body framing of AUSTRO-DAIMLER railcar.

hot-drawing or from bent plates welded together. As the parts cannot be riveted together, all units are assembled by electric arc welding (see fig. 99, an example of assembly).

4. Methods of assembly.

The parts in many cases are riveted up with the exception of such parts as the underframe, which have to stand large stresses. Welding is then an auxiliary process, its use being determined by the ease with which it can be done (Belgian railcars).

Some builders, however, have deliberately adopted welding.

For example :

— the C. K. D. railcars of the Czechoslovak State Railways, in which the longitudinal and cross members of the underframe are welded electrically, while the floor is riveted to the underframe.

— Figure 100 shows the body of a Fiat rail motor car wholly assembled by electric arc welding or butt welding in the case of heavily stressed members, electric spot or continuous welding for less important parts of the framing and for securing sheet panelling.

— The 4- and 8-wheeled SKODA railcars of the Czechoslovak State Railways (fig. 101) are completely assembled by electric continuous welding.

Gas welding is little used, and the general tendency has been towards electric welding under all forms.

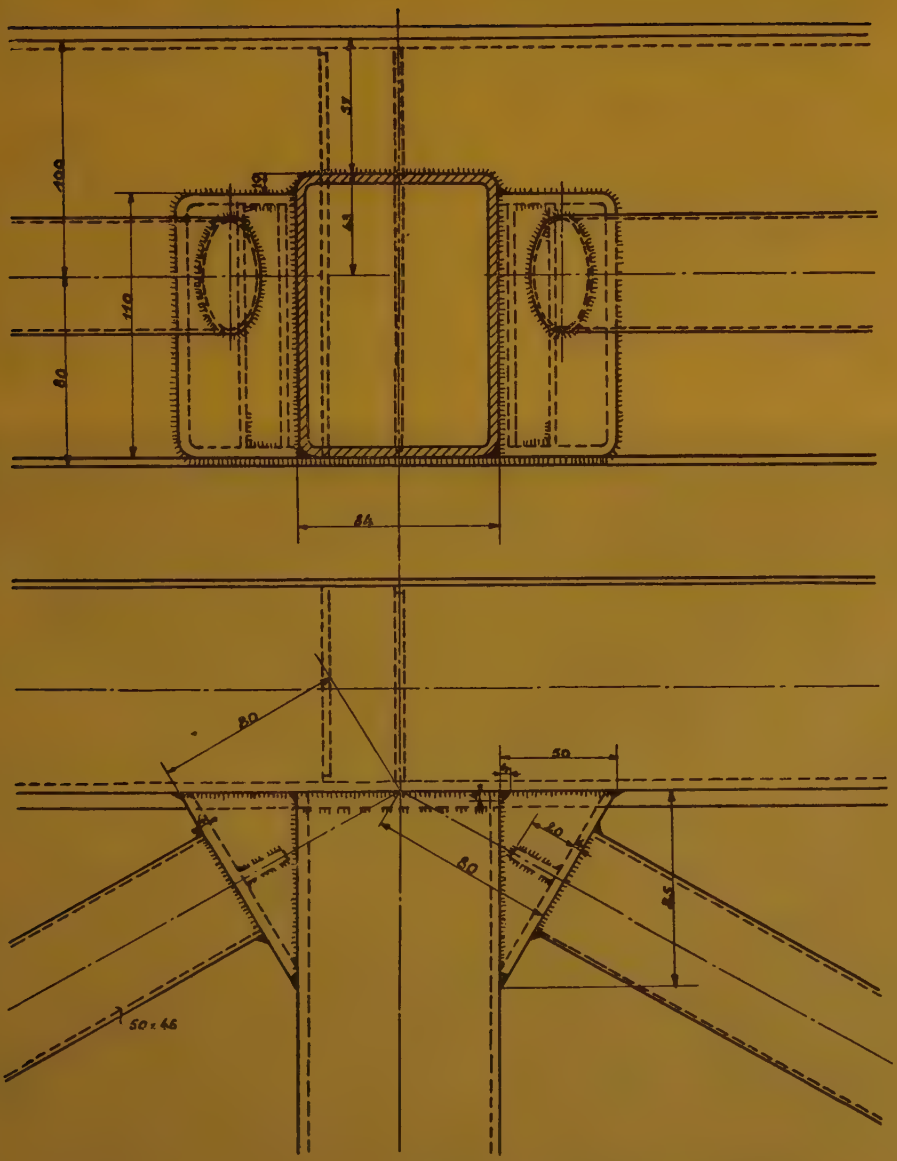


Fig. 99. — Dutch triplets. — Example of assembly (welded tubes).

IV. — Description of a few modern railcar underframe-body units.

1. Rigid frame, light body.

BUGATTI (France).

a) *Underframe.*

The underframe consists of two pressed-steel sole bars 8 mm. (5/16 inch) thick, the form being that of a girder of equal strength. These two sole bars are cross-braced in an absolutely rigid manner by intermediate cross bearers, also made of pressings, riveted to the soles.

In line with the centre pins there are two intermediate cross members placed close together, forming a very strong caisson which acts as the centre bolster.

b) *Body.*

The all-steel body consists of 5 independent sections, the middle one, which contains all the motor equipment; the driver's cabin; the luggage compartment, and the lavatory; the ends, of special shape, and the two intermediate sections. These five sections are assembled together by rubber blocks, which are heavily compressed by the tightening up of bolts.

These five parts can therefore move

Fig. 100. — FIAT railcar (Italy). — Underframe and body framing.

relatively to one another, but the tightness of the whole is obtained by the compression of the rubber blocks.

The intermediate sections each have a door on either side of the vehicle; this door, in pressed plate, opens outwards; it is fitted with a safety lock. Each part of the body is built up of a certain number of girders in double T section braced together by rolled sections of the same form, assembled by butt-welding.

The all-metal sides and roof are double-panelled with « Celotex » (compressed cane fibre) in between.

The body is carried on the underframe by a certain number of cup-shaped supports secured to the sole bars, and in which rests a spherical pivot attached to the body. A block of indiarubber is placed between the pivot and the cup (cf. fig. 86).

The unit has two compartments, each of which can hold 24 passengers, connected by a gangway without doors.

The side corridor gives access to the driver's compartment, the luggage compartment, and the lavatory.

The seat backs are reversible to meet the passengers' wishes.

The windows are fixed and fitted with safety glass.

Fig. 101. — Skoda railcar of the Czechoslovak Railways.
View of underframe and body framing.

24- and 56-seater MICHELINES (France).

The frame and body of the 24-seater Michelines consist of a series of trellis girders cross-braced by the carlines and cross stays.

The whole is fastened by four links to the bogie frames. The body framing is assembled by riveting the thinner parts in bent plate, and by welding in the case of the tubes.

The panelling (light plate lined inside with imitation leather) in no way adds to the shock-resisting strength.

This ultra-light construction adopted to reduce the load on the pneumatic tyres has been given up in the later larger-capacity vehicles.

Indeed, the 56-seaters have rigid frames in bent or pressed sheet steel (fig. 87). The sole bars have a large moment of inertia. The body is built up of pressed aluminium sheets, bolted together, and bolted to the underframe, impregnated wood laths being inserted between the two parts.

The frame is carried on two bogies on which it rests on 8 supports (4 per bogie).

Whilst the construction remains extremely light, it shows a development towards a more rigid type of vehicle, as is shown by the following figures :

Weight per metre (per linear foot) of body length :

24-seater *Micheline :* 558 kgr. (1 230 lb.).
56-seater *Micheline :* 788 kgr. (1 737 lb.).

4- wheeled SKODA railcars,
Czechoslovak State Railways.

The underframe is electrically welded; the sole bars are of the lattice type; their lower flange is made of steel tubes and also acts as a compressed-air brake pipe. The upper flanges and cross bearers are angle bars. The solebars are cross-braced by plates carrying the body.

2. Body and underframe forming a rigid unit.

« LA BRUGEOISE » (Belgium) twin railcar.

This set consists of twin units of streamlined form.

The two bodies are metal and form two rigid tubular girders carried on three bogies, wood being used for lining out the interior only.

The underframe and the sides are in steel, and the roof is built up of steel and light alloys.

In building the units, large use has been made of rolled sections and pressed plates, assembled by riveting or by electric continuous welding.

Special high-tensile steels were not used; rustless steel, aluminium and its alloys, have been used for fittings, for the roof, and for certain details.

SCHNELLTRIEBWAGEN (Germany).

The underframe is formed of Z bars which run straight through in line with the doors. The two longitudinals forming the lower frame are connected by light cross members of U shape. The ends are strengthened by strong caissons which act as buffers by the simple addition of two hemicylindrical blocks of indiarubber carried in two side buffer cases. The roof skeleton is completed by transverse members tied together by the side walls, which in this way add to the rigidity of the body.

The outside panelling is steel plate 2 mm. (5/64 inch) thick below and 1.5 mm. (1/16 inch) thick above the waist rails.

The roof arch is made of rounded plate 4 mm. (5/32 inch) thick, which is also used for the turned-down ends of the roof. The middle part of the roof, which is slightly curved, is made of 6-mm. (15/64 inch) plywood covered with two thicknesses of special fabric.

The inside of the body is covered in 3-mm. (1/8 inch) plywood.

When building the body frame ample use was made of « St 52 » (33 Engl. tons tensile) steel, which can be classed among the chrome-copper steels, the different parts being welded together whenever possible.

DUTCH triplet sets.

The body skeleton has been built up from tubes of rectangular section, which were preferred to rolled sections in order to reduce the weight without diminishing the strength. These tubes have been obtained, starting from the Mannessman circular-section tubes, by hot drawing, which gave them the required rectangular section. Il appears that their price is not much higher than that of ordinary rolled sections.

The whole of the tubes is assembled by electric welding; the side panels are also welded to the body framing. The centre body has been built up more strongly in view of the weight of the motor equipment carried in it.

The ends of the train are streamlined to reduce the air resistance.

In addition, the sides of the bodies are continued downwards by a petticoat in sheet steel which covers the running gear, to prevent the formation of eddy currents under the body.

Special steels have not been used; ordinary copper bearing steel has been used exclusively.

GANZ railcars (Hungary, Belgium).

This builder has adopted, for his modern railcars, the type of frame and body which forms a rigid girder of the *Vierendeel* type, with 2 or 3 supports.

The underframe alone is designed to take all shocks, should the vehicle be involved in a collision.

The main parts, the underframe and the body framing, are very much strengthened by the steel panellings of the body which are welded to the underframe and act as gusset plates, as do the curved roof plates.

The body pillars are riveted or arc-welded to it the whole depth of the sole bars. Chrome steel of 50/60 kgr. (31.75 to 38.1 Engl. tons) tensile strength (see table V) is used throughout.

FIAT (Italy) (see fig. 100).

The underframe and the body skeleton are one rigid unit although very light, and are carried on two bogies through two cast-steel body bolsters.

The body is carried on each bogie by means of two metal plates lined with indiarubber, resting on 4 steel rollers secured to the bogie sole bars. The bogie centre, embedded in a rubber pad, is a spherical bearing.

Except for the upper part of the roof and the two ends, which are covered with aluminium sheeting, ordinary steel is used throughout.

The body framing is mainly built up of rolled-steel sections.

FRANCO-BELGE (Nord Railway, France).

a) *Body framing.*

The whole of the body and underframe forms a tubular structure based on the principles adopted in the case of all-metal coaches for fast trains.

The underframe consists of two sole bars of U shape, of pressed steel 4 mm. (5/32 inch) thick, which are rounded at the leading end; they are cross-braced by pressed cross bearers electrically welded, and riveted together.

The body is built up of steel members 3 mm. (1/8 inch) thick, also of pressed steel, and is welded and riveted.

The side panels of the body are riveted along their lower edge to the top of

the sole bar; the joint is completed by electric continuous welding.

The roof consists of steel sheeting 1.5 mm. (1/16 inch) thick.

b) *Outside shape of the body.*

The outside shape of the body was the outcome of many tests on models in the wind tunnel. It takes into account the fact that the rake has to run in both directions.

These tests have led to a removable screen in duralumin sheeting, being fixed under the frame, which closes in as far as possible the running gear.

The side lights, which are fixed, are set back 4 mm. (5/32 inch) only from the outside; the design of the doors also coincides with that of the outside of the body, so as to prevent the considerable increase of air resistance resulting from the usual setting of the lights. In the same way, the train lights do not project and are protected by glass which forms a practically continuous surface with the walls. Finally the exhaust chimney has been streamlined.

Thanks to these precautions an air resistance coefficient of 0.32 has been obtained for the models in the air tunnel, whereas the same coefficient for an ordinary railway vehicle may be as much as or even exceed 0.80.

4-WHEELED SKODA RAILCAR
(Czechoslovak State Railways).

The underframe, the body frame and the inside sheet panelling are electrically welded and form one solid unit. The lower part of the railcar is shrouded in by a petticoat of sheet metal, which reduces the air resistance when running.

* * *

CHAPTER XI.

ARRANGEMENTS.

I. — Sound and heat insulation of the passenger compartments.

1. Sound insulation.

The suppression, or rather the reduction, of noise and vibration inside compartments is an important factor in making railcars comfortable.

The suppression of noise is a very complex and delicate problem which requires a careful and methodical investigation; this problem has many resemblances with that which arises in aircraft and some of the conclusions come to by the engineers specially dealing with noises in aircraft, Mr. Stephen ZAND, for example, might well be adapted to railcars.

Practically, noise would be diminished :

a) by a reduction of the vibrations;

b) by a reduction in noise transmission through the various parts which make up the vehicle;

c) by absolute tightness of the walls.

a) *Reduction of vibrations.*

To damp out the vibrations which are transmitted to the passenger compartment, it is necessary to break the continuity between the different sources of vibration and the inside of the body, and this is done by inserting blocks of indiarubber between different parts of the railcar :

1. Between the tyres and the axles, which gives the elastic wheels. The various methods used so far have not given full satisfaction, except the pneumatic tyres used on the MICHELINES, and to a lesser degree, wheels of the DAIMLER type.

TABLE VI.

HEAT-INSULATING AND SOUND-DEADENING MATERIALS.

Usual description.	*Nature.*	*How supplied.*	*Used for.*	*How fastened.*	*Remarks.*
Wood.	Poplar.	Boards or plywood.	Floor itself.	Nailed.	Usually covered with linoleum, with or without additional heat insulation.
Compressed cane fibre.	Compressed cane fibre.	Sheets or strips.	Lining body sides or roof (usual). Sometimes used as an additional floor covering.	Glued or nailed (nails with welded heads and points burred). Screwed down with washers.	...
Compressed cork.	Cork.	Do.	Lining sides, floor and roof.	Nailed. Glued.	...
Cork scrap.	Cork.	Pieces.	Lining the sides and roof. Lining of corrugated sheeting carrying the floor in some railcars.	Sprayed with compressed air gun after coating with paint.	Denmark.
Alfol.	Crumpled aluminium sheets.	Sheets.	Lining body sides and roof.	Held in place by wires.	For heat insulation exclusively.
Asbestos scrap.	Asbestos.	Pieces.	Side and roof sheeting.	Sprayed with compressed air gun on previously tarred plates.	Drawback that covering softens in summer (inside paint stained).
Rubber carpet.	Ordinary rubber. Sponge rubber.	Sheets or strips.	Floor covering.	Laid or nailed.	Rubber sheets usually used as a vibration absorber under a carpet or linoleum. In some cases the rubber forms the top covering.
Linoleum.	...	Do.	Do.	Do.	
Felt.	Wool or cotton.	Roll.	Lining floors and sides.	Simply inserted or glued.	...
Compressed wood wool.	...	...	Lining roof, sides, and floor.	...	Finland.

2. Between the body and the running gear.

3. Between the engine and its support. This latter precaution is particularly important if the engine is inside the body.

b) *Transmission of noise by conduction through the various parts of the railcar.*

Noises transmitted in this way can be reduced by the use of rubber as above; but to reduce them still further, the use of quite special sound-deadening materials would be desirable. Systematic tests ought to be made to classify the sound-deadening values of the different materials used.

Table VI gives the essential data for the various materials in ordinary use.

The railcar floor construction plays an important part, and among the methods used to prevent noise being transmitted through the floor, the following may be mentioned.

1. Corrugated steel sheeting lined on its upper face with compressed cork, to provide a level horizontal surface covered in turn by an insulating material on which linoleum is laid.

2. The use of a double floor, the air imprisoned between the two parts providing an excellent insulation.

The principle of an air gap between the inner and outer walls is also used for the body sides and roof.

c) *Transmission of noise by the surrounding atmosphere.*

To minimise as much as possible the noise so propagated, the railcar should be made as airtight as possible, as noise penetrates through the smallest opening. Too often have the builders been satisfied with covering the engine with a metal bonnet, either single or double, and also separating the engine compartment from the passenger compartment by a luggage compartment forming an air lock.

2. Heat insulation.

No systematic investigation has been made into heat-insulating materials and methods in connection with railcar bodies; most frequently the arrangements adopted against noise transmission are used at the same time to reduce heat exchanges.

The materials used, with their principal characteristics and the way they are employed, are shown in table VI.

II. — Windows and doors.

When dealing with fixtures it is relatively easy to make the vehicle air- and watertight; the doors and windows, however, which open, have to be absolutely tight when shut, and at the same time only require the minimum effort to be opened or shut.

Drop lights can be divided into several classes as regards arrangements for providing tightness :

a) *Fully sliding light,* dropping into the case below, with felt or rubber packing.

Water is allowed to enter into the casing below the windows and escape freely from it; evaporation is hastened by the air current through it (A. D. N. of the French Railways).

b) Only the top part of the window is moveable, and slides in front of the other half; a simple band of rubber makes the joint between the two half lights, and in the channel of the moveable half light when shut.

The lower panel of the window can easily be made watertight (certain A. D. N. and Renault railcars on the French Railways).

Method of operating moveable lights.

In railcars of older types, the light was opened or shut by a leather strap, but all up-to-date rail motor cars are fitted with a winding-up gear of the automobile type, usually with a spring equalising device.

These equalisers are housed under the light if this can be fully dropped.

In some cases the moveable half lights are fitted on the sides with clips engaging in the side racks (Renault, France).

Doors.

The doors, when shut, are made tight in most cases by special rolled sections in rubber.

The doors usually are hinged, opening either inwards or outwards.

Certain railcars are fitted with sliding doors (Holland, Belgium, French A. D. N. railcars). Others have folding doors of the « portfolio » type (doors into the luggage compartment on the French Renault).

In all cases, the doors are either fitted with a safety lock or a double-action lock.

On certain railcars in Italy and Hungary, the driver can ascertain, thanks to an electrical device, that all the doors are shut.

Kinds of glass used.

All the railways use safety glass for the driver's compartments. « Triplex » is preferred to tempered glass, because after having been broken by a shock it retains sufficient visibility for driving.

In this connection mention may be made of the « Sigla » glass, used in Austria, which does not become translucid like the « Triplex », nor explode like the « Securit ».

As regards passenger compartments, safety glass is not usually imposed by a government regulation. Its use, however, is becoming general in the form of tempered glass, of which « Securit » is the prototype in France.

III. — Interior fitting out.

Passenger compartment.

From the operating point of view, railcars can be divided into two classes :

— Accelerated local trains on secondary lines with little traffic;

— Express trains between large centres relatively short distances apart.

In these two cases the time the passengers are in the vehicle does not exceed a few hours, and consequently the interior arrangements can be made simpler than on main-line stock. In particular, most railcars have only one bay without any partitions between the various compartments.

The interior arrangement thus very often approaches that of a modern road motor car. The compartments are fitted either with fixed seats, with fixed backs, seating two or three, covered with imitation leather or fabric (1st class) (see fig. 102), or fixed seats with movable backs, or again individual reversible seats (see fig. 103).

For some time a special investigation has been undertaken to improve the reversible seats enabling passengers to always face the running direction.

* * *

Triplet railcars.

We deemed it interesting to give hereafter, grouped on one plate (fig. 19), the diagrams of the various triple-unit rail motor sets now in service or under construction, namely :

Reichsbahn — electric or hydraulic drive — under construction.

Belgian National Rys. Co. — electric drive — under construction.

Danish State — electric drive — under construction.

Nord (France) — electric drive — in service and under construction.

Netherlands Rys. — electric drive — in service.

Italian State — mechanical transmission — under consideration.

Messrs. Michelin, Bugatti, and Renault, have just put into hand triplet sets for the French State Railways.

IV. — Meals served in railcars.

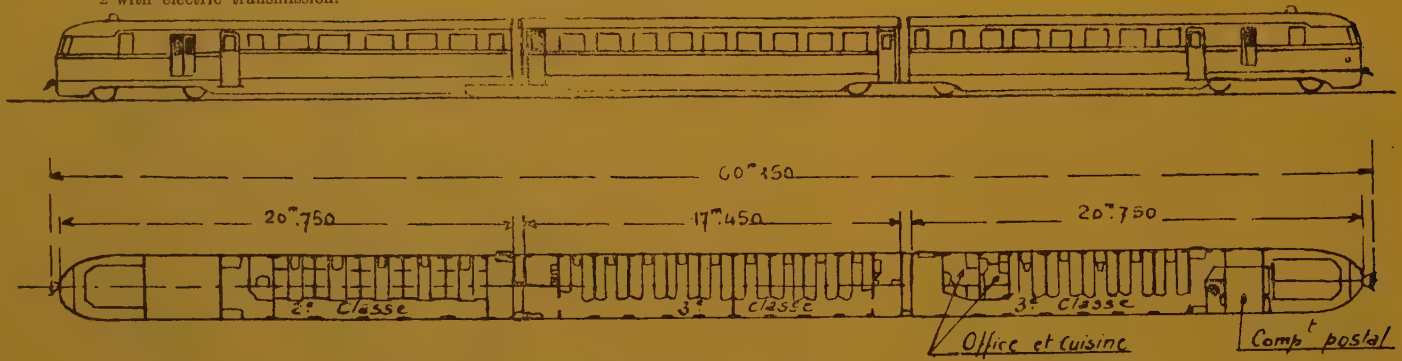
Several railways provide light meals in some of their railcars.

As the companies wished to carry the greatest possible number of passengers, the space set aside for these services was

Two 600-H.P. diesel engines.
3 with hydraulic transmission.
2 with electric transmission.

GERMANY (5 under construction).

Number of seats { 2nd class : 30.
3rd class : 109.

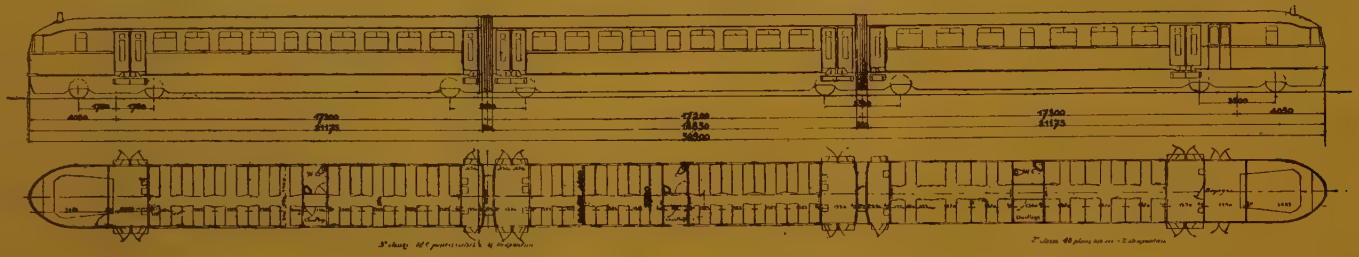


Note: Office et cuisine : pantry and kitchen. Compt postal = Post Office compartment.

Two diesel engines, 400 H.P. (approx.)
Electric transmission.

BELGIUM (8 under construction).

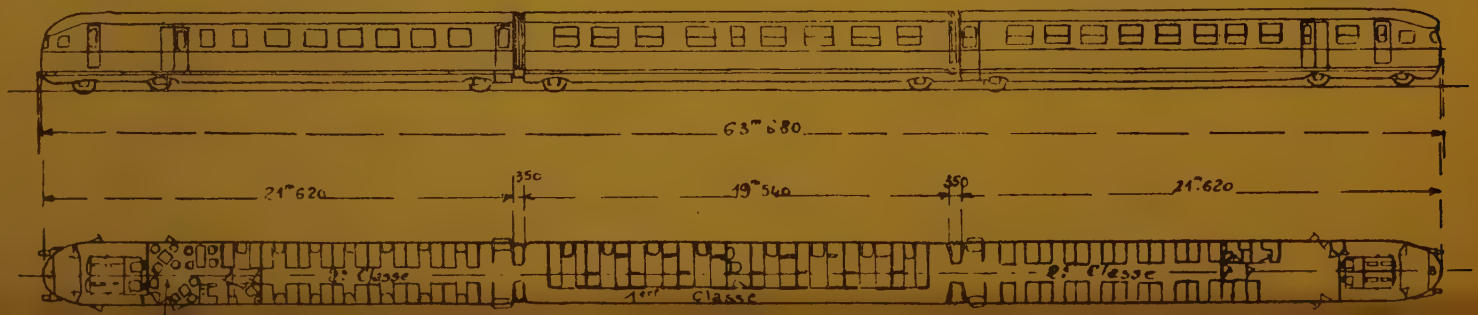
Number of seats { 2nd class : 50.
3rd class : 179.
Weight : 118 t. (116.1 Engl. tons).



Four 275-H.P. diesel engines.
Electric transmission.

DENMARK (4 built, in service from 15th May).

Number of seats { 1st class : 36.
Common class : 108.
Restaurant : 12.
Weight (design) : 118 t. (116.1 Engl. tons).

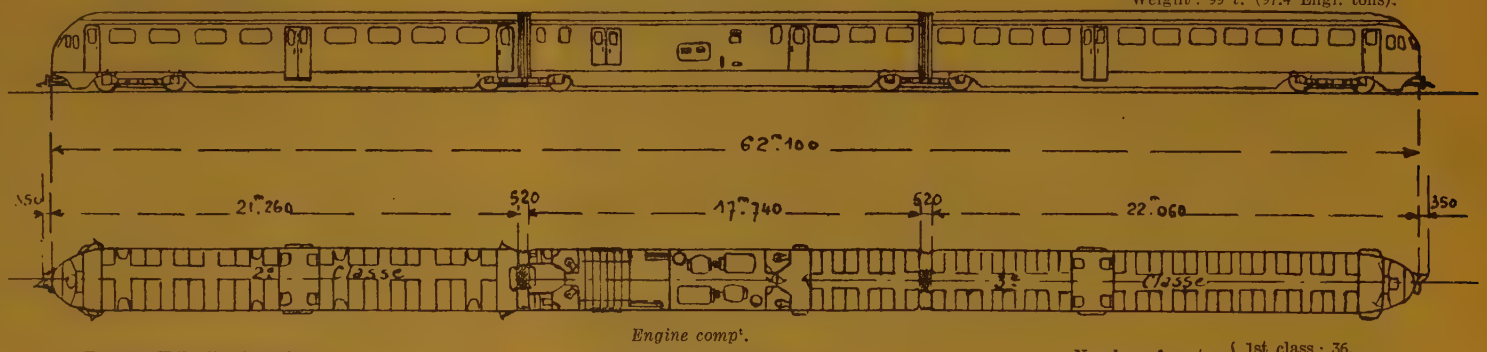


Note: «Bar» in the middle vehicle should be read « Cuisine » (kitchen). Furthermore all vestibule doors except at both ends open inside instead of outside as shown on the diagram.

Two 410-H.P. diesel engines.
Electric transmission.

HOLLAND (40 in service).

Number of seats { 2nd class : 48.
3rd class : 112.
Weight : 99 t. (97.4 Engl. tons).



Engine comp^t.

Two 400-H.P. diesel engines.
Mechanical transmission.

ITALY (projected).

Number of seats { 1st class : 36.
2nd class : 56.
Weight (anticipated) : 75 t. (73.8 Engl. tons).

Fig. 104. — Diagram of triplet railcars of various countries.

Fig. 102. — FIAT railcar (Italy). — Interior arrangement.

so small that the installation has been particularly difficult to carry out. Then, too, the weight of the equipment and accessories, as well as the fuel to be used, has made the problem still more complicated. However, the question has been very elegantly solved, and we give below an enumeration of installations in service at the present time, as well as of others for railcars under construction.

Railcars under construction.

The BUGATTI twin railcars of the Paris-Lyons-Mediterranean and the FRANCO-BELGE triplet sets of the French Nord are now provided with a restaurant equipment (worked by the International Sleeping-Car Company). The space reserved for the buffet-kitchen is very small and the staff has to use Butane gas stoves when preparing hot drinks or dishes.

A bar has also been installed on the SCHNELLTRIEBWAGEN so that cold and hot drinks can be served, the hot drinks being heated electrically.

Railcars under construction.

The International Sleeping-Car Company is at the present time designing the equipment of three types of railcars under construction : FRANCO-BELGE triplet sets of the French Nord Railway, the triplet sets of the Danish State Railways, and those of the Italian State Railways.

Fig. 103. — Bugatti railcar (French State Railways). — Interior arrangement.

The space provided for the buffet-kitchen on the French Nord triplet sets is larger than that on the rakes in service, and the Butane gas stove has been replaced by a Butane gas oven; passengers will be able to order the same meals as in the dining cars.

On the Danish triplets only very simple meals and dishes are served, the stove and kettles being electric, as is the ice machine.

In the case of the Italian State triplets, the space set aside for the kitchen and pantry is similar to that of the Pullman cars and the installation, though not definitely decided upon, will be similar to those on the Pullmans.

The triplets now under construction for the Deutsche Reichsbahn are also being fitted up with a buffet.

* * *

CHAPTER XII.

HEATING AND VENTILATION.

A. — Heating.

Most builders endeavour to use the heat in the diesel engine exhaust, not transformed into energy, for heating their railcars.

Certain builders have, however, preferred not to run any risk of interfering with the working of the engine, and have therefore installed hot-water heating from an independent boiler, a method which is essential in districts where there are wide differences in temperature, or when it is desired to make quite sure that the railcars will be properly preheated.

The methods generally employed for heating railcars can be classified under four headings :

1. — Heating by the exhaust gases;
2. — Heating by the engine cooling water;
3. — Heating by hot air, the temperature of which is raised by :
a) the exhaust gases;
b) the cooling water.
4. — Heating by means of an independent boiler.

1. Heating by the engine exhaust gases.

This method has the advantage of being economical and not requiring any special installation.

On the other hand, the heating power obtained is obviously limited, as it depends directly upon the way the engine is working, so that it may be insufficient in periods of severe cold, or in less cold weather during the descent of long gradients on which the engine is not developing any power.

This type of heating is generally used :

1. On petrol railcars, on which the number of heat units available is greater than in the case of diesel engines;

2. On diesel railcars the power of which is high for the services being covered;

Heating is by plain or preferrably by finned tubes which latter assist the dispersion of the heat.

The greatest precautions must be taken to ensure these pipes being tight in order to prevent poisonous gases getting into the compartments.

Regulation of the heat is not automatic, and is generally controlled by the driver, by means of a valve which regulates the quantity of exhaust gas admitted into the heating pipes.

It should be noted that this method of heating has a far from negligible influence on the working of the engine, as it impedes the escape of the exhaust gases, and therefore sets up a counter-pressure in the cylinders.

Heating by the exhaust gases is widely used in France [Renault railcars; so-called « Standard » railcars of the Aciéries du Nord (A. D. N.); Bugatti railcars with four 200-h.p. petrol engines]; in Italy, Fiat railcars; and in Czechoslovakia.

2. Heating by the engine cooling water.

As with the exhaust gases, heating by circulating the cooling water of the engine has a limited capacity, depending upon the way the engine is worked.

In order to meet the lack of heat in cold weather, or when running under low power, the equipment is generally completed in large-capacity railcars by a standby heating plant (hot water heating by means af an independent boiler or electric heating).

Regulation of the heat is sometimes automatic, by means of a thermostat which comes into action as soon as the temperature of the engine water exceeds a certain limit, by diverting part of this water towards the engine radiator.

Preheating is obtained either by the standby heating installation when this is fitted, or by an outside source of

steam supplying the normal circuit of the cooling water, or a special preheating circuit.

This method of heating is used in Austria (WIEN-SIMMERING railcars fitted with one 160-H.P. diesel engine); in France (COMPAGNIE GÉNÉRALE DE CONSTRUCTION railcars, with one 135-H.P. diesel engine; BAUDET-DONON-ROUSSEL railcars with one 105-H.P., C. L. M. diesel engine; CHARENTAISE railcars with one 80-H.P. Junkers diesel engine); in Finland (railcars with one 150-H.P. M. A. N. diesel engine), in Hungary (various designs with diesel or petrol engines), and in Czechoslovakia (various railcars).

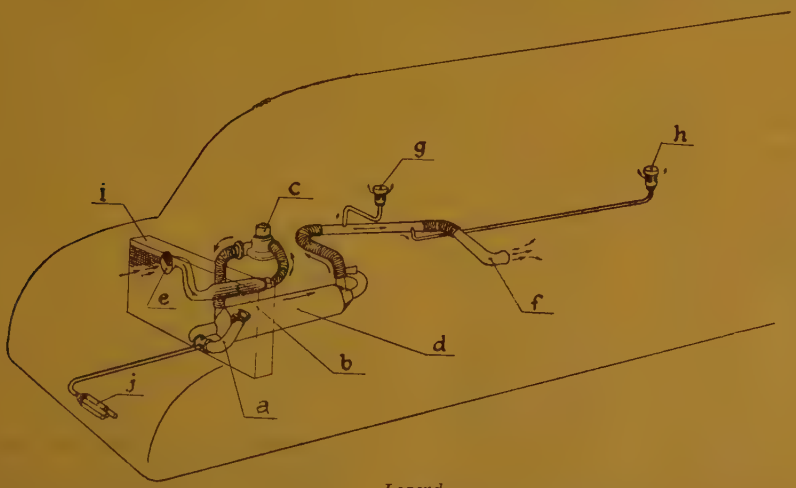
3. Heating by air brought to the desired temperature by the exhaust gases or the engine cooling water.

The air coming from the outside is heated :

— either by circulation round the exhaust gas piping,

— or by radiators through which the engine cooling water is circulated.

Both these methods are economical as they do not require any piping being installed, the hot air being admitted into the compartments through ventilating inlets. Circulation of the warm air is obtained through the speed of the vehicle itself, or what is better, by electric fans. These methods combine very well



Legend :

a = Exhaust gases from engine.
b = Air from the atmosphere.
c = Fan.
d = Air heater.
e = Suction of air from atmosphere.
f = Warm air main pipe.
g = Warm air inlet into driver's compartment.
h = Warm air inlet into lavatories.
i = Radiator.
j = Warning device (coming into action when the pressure drops).

Fig. 105. — Hot-air heating installation on AUSTRO-DAIMLER railcar (Austria).

with the ventilation properly speaking of the railcars, and even in the case of the cooling water, with their refrigeration; the latter is consequently particularly interesting in the case of railcars with fixed window lights.

Figure 105 shows the hot-air heating system installed on the AUSTRO-DAIMLER railcar with two 80-H.P. petrol engines, of the Austrian Federal Railways.

The outside air, sucked in by a fan, is introduced into a heater, through which the exhaust gases are circulated.

A main pipe conveys the heated air

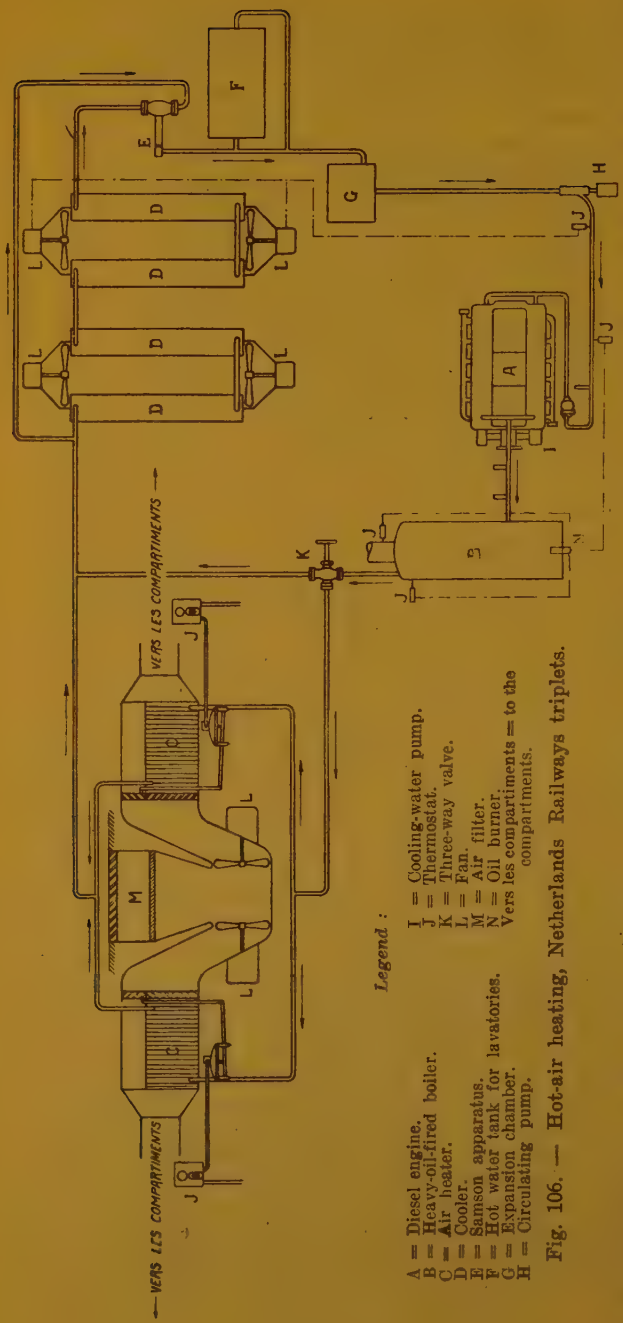


Fig. 106. — Hot-air heating, Netherlands Railways triplets.

to the compartments, and secondary pipes to the driver's compartment and the lavatories.

The method of heating by hot air heated by the engine cooling water is used in Germany on rail motor cars of various types, in Holland on the triplet railcars with two 410-H.P. Maybach diesel engines, and in France on the Michelines.

Figure 106 shows the installation on the Dutch sets, the working of which is the following :

The cooling water from each engine passes through two radiators in which the air is heated before being introduced into the compartments.

When the weather is very cold, the water from the engines is further heated in an auxiliary oil-fired boiler before entering the radiators.

This boiler is put into action by a thermostat as soon as the temperature of the cooling water on its way back to the engine falls below a certain limit.

4. Heating by independent boiler.

This method, similar to that used in central heating installations, is the one chiefly used for large-capacity railcars, especially for multiple units.

It has the following advantages :

— The power of the boiler is proportioned to the volume to be heated, and consequently it is easy to obtain the desired temperature;

— Flexible working;

— Easy regulation;

— The heating plant is independent and does not affect the working of the engine;

— The equipment can readily be used for preheating the railcar.

The drawback of this heating method is that fuel must be stored and the railcar staff is obliged to keep firing the boiler during the journey, when coke is used.

Furthermore, there are additional fire risks. In principle, such a plant consists of a vertical tubular boiler fired by coke

or fuel oil; the hot water runs into an expansion tank, circulates through the heating pipes and returns to the bottom of the boiler by a return pipe.

The heating circuit consists of a single pipe, finned radiators, or in certain cases ordinary house radiators.

Regulation, when automatic, is obtained by means of a thermostat controlling the draught (coke-fired boiler), or the fuel admission (gas-oil).

The hot water is generally circulated in the heating circuit by means of an electro-pump, fed by the accumulators of the vehicle.

In certain railcars a pipe is provided to take hot water to the engine jacket, so as to heat the engine and make it easier to start.

This method of heating has been applied on a wide scale in Germany (various railcars), in Belgium, in Denmark (FRICHS railcars with two 220-H.P. Frichs diesel engines), and in France (DE DIETRICH railcars with two 100-H.P. diesel engines, S. O. M. U. A. railcars with one M. A. N. 210-H.P. diesel engine, FRANCO-BELGE railcars with two 410-H.P. diesel engines.

B. — Ventilation.

The ventilation of railcars is on the same lines as in ordinary coaches :

— by opening the windows when not fixed;

— by ventilating apparatus.

Railcars are usually fitted with ventilators in the roof.

These act either by aspiration or by feeding air under pressure into the compartment.

The entry or the outlet of the air takes place through the natural interstices and also by the windows.

These devices are usually controlled by the passengers operating disc valves, the opening of which can be varied.

In the FRANCO-BELGE triplet railcars, the windows of which are fixed, ventilation is obtained by lateral ventilators fitted by means of ball-and-socket joints, and which the passengers can set to suit their wishes.

In the 220-H.P. RENAULT railcars, two air inlets at the ends of the vehicle build up the pressure between the inner and outer linings of the body. This air is then distributed into the compartments by adjustable ventilators.

These methods are simple and economical but no ventilation is obtained when the coach is standing.

Fans are more generally used in vehicles fitted with hot-air heating equipment. The air put under pressure by the fans passes over the heating elements before being discharged into the compartments.

The power needed to ventilate the coach varies according to the equipment from 6 to 17 watts per m^3 (17 to 50 watts per 100 cu. feet) to be ventilated; the number of times the air is completely changed per hour should be at least 12.

Ventilation by fans is therefore relatively expensive, but has the great advantage of being available for use when standing, as it is not always possible to open the windows in cold weather.

* * *

CHAPTER XIII.

FIRE PRECAUTIONS.

Proper fire organisation includes, on the one hand, preventive measures the object of which is to reduce the risk of fire to a minimum by eliminating the

causes and by retarding its spread, and on the other, the placing at the disposal of the staff concerned of adequate means for extinguishing fires at their outbreak.

A. — Preventive measures.

I. — Suppression of the causes of fire due to the railcar.

We will examine hereafter the main parts of the railcars which require special precautions.

1. Engine.

Petrol engines carry in themselves a very serious cause of fire outbreaks, which diesel engines are free of, namely back firing into the carburetter, due to the engine being badly timed, or to defective carburation. This is overcome by fitting the carburetters with antiflame devices, by careful selection of the fuel, and by filtering it on the vehicle before use.

With the diesel engine, as well as with the petrol, it is most important to prevent :

a) leakage of fuel or lubricating oil which, when falling on the exhaust pipes are apt to catch fire;

b) the passage of the exhaust pipes near parts made of inflammable materials or which may be impregnated with inflammable liquid.

The exhaust pipe is very often insulated, but when asbestos is used care must be taken that it does not become saturated with fuel. The best precaution would appear to be to cover the exhaust pipe with an additional cover in steel plate at the critical points, at the same time arranging a current of air to circulate between the lagging and cover.

2. Electric circuits.

Electric short circuits are frequent causes of fire : they may be due either to a wire breaking through mechanical causes (vibration) or through a breakdown of the insulating material through oil, and above all gas-oil.

Mechanical fractures produce short circuits on railcars chiefly when the return is made through the ground. In this case the wires should be arranged to run in covered or insulated and fireproof tubes.

Wires exposed to the action of gas-oil, under the bogie (electro-magnetic brake) or near the motor (dynamo and starter) ought to be protected by insulating coverings which are not affected by oil, of the « souplesso » type. When such protection is given particular care must still be taken to watch the condition of the sheathing, as the smallest crack in it is an open door to corrosion.

Up to the present, the builders have generally been satisfied with keeping the electric circuits away from the parts of the railcar where leakage of fuel and lubricating oil is to be feared; some of them have mounted them in special steel channels (Finnish State Railways).

3. Brakes.

The bad working of a brake (shoe or drum) is capable of producing sparks or making certain parts red hot. Builders take care not to put inflammable materials near these, or at least to protect them by metal plates.

4. Piping.

The engines are carried either on the bogie or on brackets with indiarubber pads, which allows them to move slightly relatively to the body which carries the fuel oil pipes.

To prevent this connecting piping breaking under the influence of these movements, flexible piping is used more and more, following aircraft practice.

5. Fuel tanks.

Fuel tanks and more particularly petrol tanks, usually carried under the

coach, should be protected against shocks likely to start leaks.

On the MICHELINE and BUGATTI railcars, the French Railways have adopted a system of protection similar to that of aircraft, which consists in fitting several layers of pure rubber and fabric tightly bound round the tank by a metal grill.

Certain railways use double-casing tanks with felt and poplar distance pieces between (Mozambique, MICHELINES).

In Italy very strong tanks in steel sheet, reinforced by metal rings, are preferred.

II. — Elimination of outside causes of fire.

All the measures we have just considered apply to causes due to the railcar itself; outside causes must not be overlooked.

1. Portable lights or train lamps.

Mobile lights are always electric (portable lamps with plug, lamps or torches with primary battery or accumulator).

When the driver of a railcar uses a bare-flame lamp, certain railway companies allot it a special place; others only allow the lamp to be lit outside the vehicle.

2. Filling the tanks.

When filling the tanks, the danger of fire is due to the vapours of the fuel from the reservoir, or to the latter overflowing. During filling, most railways do not allow smoking, approaching with a bare-flame lamp, or leaving the engines running. Certain railways furthermore endeavour to suppress the above two causes of fire by using a design which gives a tight connection between the flexible filling pipe and the outlet of the tank and shuts off the petrol when the reservoir is full (RELLUMIT system employed on the French main-line railways).

3. Garaging the railcars.

The railways take care not to place the railcars near locomotives in steam, and not to run them over lines where freshly dropped cinders may be found.

Certain countries (Austria, Denmark) do not apply these precautions to diesel railcars.

III. — Precautions taken to prevent fire spreading.

Unfortunately all the above measures do not protect railcars against all fire risks. When fire breaks out, it must be prevented as much as possible from spreading, so that the passengers can get out and the staff fight the fire with some chance of succeeding.

1. Construction of non-combustible or fireproofed materials.

Certain railway companies refuse to allow the use on railcars, of combustible materials not fireproofed.

Fireproofing of the wood is by impregnation (in France — Oxylene process — Incombustibilité), that of the fabric by soaking or pulverisation.

No precise rule seems to exist about the method of fireproofing to be adopted, and the conditions to be imposed for accepting these fireproofed materials. How efficacious the pulverisation process may prove to be, is still unknown.

Some railways are satisfied with protecting the wood by fireproof painting or by covering it with suitable fireproof materials (asbestos sheeting or plates with air spaces). It should be noted, on the other hand, that certain materials such as linoleum, imitation leather, etc... cannot be made satisfactorily fireproof.

2. Keeping fuel tanks away from the engines.

In order to avoid having too much fuel in store quite close to the engines, many builders locate the fuel tanks un-

der the vehicle, whence they feed a small fuel tank. Such precautions are particularly necessary in the case of petrol engines, as it has been found that a diesel railcar could be wholly destroyed by fire without the gas oil contained in the tank catching fire.

By means of special devices, the passage of fuel to the feeding tanks or engines can be cut off immediately. For example, the Dutch railcars on which it is sufficient to operate two cocks placed together on one of the body sides, one of which cocks insulates the feed tank from the engine while the other cuts off the feed to the small fuel tank; the Italian and French railcars (MICHELINE or BUGATTI) in which the action of a lever or switch cuts off the fuel from the engine.

3. Closing the electric circuits.

It should be noted that most of the builders have fitted a main switch for the electric circuits, handy to the driver.

4. Cleanliness.

All these precautions would be of little avail if the railcars were not kept absolutely clean.

They should be cleaned frequently so as to remove all deposits of dirty fuel and grease, which are apt to cause fires, especially on diesel railcars.

As a matter of fact gas oil is as inflammable as petrol when heated to 80° C. (176° F.), and while petrol evaporates quickly once spilled, gas oil spreads everywhere, even to a considerable distance and does not evaporate. Furthermore, an incombustible material burns very easily when impregnated with gas oil.

On the other hand, the diesel engine is in itself much less clean than the petrol engine : this is due to the abovementioned properties of fuel oil and to constructional features (injectors).

B. — Fire extinguishing methods.

Railcars are as a rule fitted with extinguishers, either portable or fixed, the latter sometimes working automatically.

In addition, certain Administrations are providing in their railcars fire detectors with alarm signals, which arrangements can be very useful on railcars with several driving compartments (detectors fitted in Germany on petrol railcars).

The types of extinguishers used by the different Railway Administrations consulted are as follows :

a) Extinguishers with fire-proofing liquid (Nasslöscher, Deutsche Reichsbahn) ;

b) Carbon-dioxide foam extinguishers (either ordinary foam for extinguishing fires of hydrocarbons without alcohol, or special foam for extinguishing hydrocarbon fires with alcohol) (French, Italian, Belgian and Finnish Railways) ;

c) Methyl bromide extinguishers (French and Hungarian Railways) or a mixture of similar products (mixture of ethyl bromide and brom-ethyl used in Germany) ;

d) Tetrachloride of carbon extinguishers (Austrian, Danish, French, German, Czechoslovak railways, etc...) ;

e) Carbon-dioxide snow extinguishers (French railways).

Mention may also be made of apparatus with powder, a few of which are used on the Hungarian railcars.

The extinguisher with carbonic foam is cheap, but takes up much room; the foam dirties much and is a good conductor for electricity.

It cannot be used on railcars fitted with electric transmission nor on those running over electrified lines.

Methyl bromide, carbon tetrachloride, and carbonic snow do not have these drawbacks.

Methyl bromide unfortunately is very dear and very volatile (boiling point : 4.5°), it necessitates special precautions

in making the apparatus as regards tightness, which makes it still more expensive.

Its efficiency is 2 to 5 times greater than that of carbon tetrachloride; it is much less poisonous than the latter, which makes it often used, especially in the case of fixed apparatus of high capacity.

Tetrachloride, in spite of the two drawbacks mentioned above, has its advocates thanks to its very low price : it is therefore preferred for use in parts of the vehicle inaccessible to the passengers.

Carbonic snow has great extinguishing power but the room taken up and the weight of the carbonic dioxide cylinders and the complicated piping limit its use (Paris-Lyons-Mediterranean, France).

Different railway companies have confirmed the efficacy of extinguishers in their railcars, this efficacy having been demonstrated by fires put out in service or during tests of the apparatus.

Fire-extinguishing methods in railcar depots.

Besides the extinguishers fitted on the railcars, extinguishers of greater capacity are kept in the depots, either portable or on wheels (20, 50 to 100 litres = 4.4, 11 to 22 Br. gallons) in the case of foam extinguishers, 5 kgr. = 11 lb. in the case of the tetrachloride extinguishers, etc....) as well as sand with shovels.

Except in Hungary, no regulations as regards the number and capacity of extinguishers to be employed according to the number of rail motor cars garaged appear to have been issued. This question cannot, moreover, be solved uniformly; the measures to be taken depend on the state of the surroundings and on the pre-existing local means of fighting fire (hydraulic pumps, etc...). On the Royal Hungarian State Railways two methyl bromide extinguishers of a capacity of 3 kgr. (6.6 lb.) are used for every five rail motor cars garaged.

* * *

To sum up, all the railways have attached great importance to the solution of the question of fire protection and have at their disposal to-day efficient extinguishers adapted to the various possible cases, and which have proved their value in service.

* * *

CHAPTER XIV.

RAILCARS IN THE VARIOUS COUNTRIES.

Germany.

On the 1st January 1935, Germany had 168 railcars in service and 212 under construction i. e. :

Railcars in service.

— 38 petrol railcars with mechanical transmission;

— 129 diesel railcars (87 with mechanical transmission, 41 with electric transmission, and 1 with hydraulic transmission);

— 1 steam railcar.

Railcars under construction.

— 203 diesel railcars (60 with mechanical transmission, 131 with electric transmission, and 12 with hydraulic transmission);

— 9 steam railcars.

All these railcars can be driven in both directions and have two driving compartments; most of the railcars are bogie vehicles.

The stock of the future is likely to be

made up of bogie railcars with trailers, of a standardized type, the trailers having a driving compartment in order to make the set reversible; these railcars would have diesel engines developing about 400-H.P.

The Reichsbahn, in close collaboration with the builders, is now carrying out very interesting tests in connection with the three following points :

1. Use of the hydraulic transmission, VOITH or other system, for powers up to 600-H.P.

2. Use of condensed steam on railcars of the DOBLE system, designed by Messrs. BORSIG and Messrs. HENSCHEL.

3. Increase in power of the diesel engines by the use of supercharging (Maybach, M.A.N.).

Four-wheeled railcar with 120-H.P. diesel engine (10 vehicles in service, 9 under trial or construction).

One Daimler diesel engine, 120-H.P. at 1 700 r.p.m., located in the middle of the vehicle, under the floor.

T.A.G. mechanical transmission, constant-mesh gear box — 4 speeds.

40 seats. Weight : 14.5 t. (14.3 Engl. tons).

Maximum speed : 72 km. (44.7 miles) an hour.

Eight-wheeled railcar with one 410-H.P. diesel engine

(21 vehicles in service, 102 under trial or construction).

One Maybach diesel engine, 410-H.P. at 1 400 r.p.m.

Electric transmissions of various designs. 72 seats. Weight, 41 t. (40.4 Engl. tons).

Maximum speed : 110 km. (68.3 miles) an hour.

Eight-wheeled railcar with one 175-H.P. diesel engine

(42 vehicles in service).

Maybach diesel engine, 175-H.P. at 1 400 r.p.m.

Maybach mechanical transmission, constant-mesh gear box with four speeds.

2 driving axles driven by jack shafts and connecting rods.

71 seats. Weight, 41 t. (40.4 Engl. tons).

Maximum speed : 65 km. (40.4 miles) and 80 km. (50 miles) an hour.

Four-wheeled railcar with one 150-H.P. diesel engine (10 in service) (fig. 107).

One 150-H.P. six-cylinder M.A.N. diesel engine.

Electric transmission, B. B. C. system.

40 seats. Weight, 17.0 t. (16.7 Engl. tons).

Maximum speed : 70 km. (43.5 miles) an hour.

12-wheeled « Schnelltriebwagen » (Express twin railcar) with two 410-H.P. diesel engines.

(1 set in service, 13 under construction) (fig. 108).

Two Maybach diesel engines, each 410-H.P. at 1 400 r.p.m.

Body composed of 2 units on three bogies.

Gebus electrical transmission.

Each outer bogie carries a diesel engine and a generator; the middle bogie carries the traction motors.

102 seats. Weight, 77 t. (76.7 Engl. tons).

Maximum speed : 160 km. (100 miles) an hour.

Figure 55 shows the driver's stand of the « Schnelltriebwagen ».

300-H.P. steam railcar

(1 in service, 7 under construction) (fig. 109).

2 Doble high-pressure boilers with

Fig. 107. — 4-wheeled railcar with one 150-H.P. M.A.N. diesel engine, with one trailer.

Fig. 108. — 12-wheeled « Schnelltriebwagen » (Express twin railcar) with two 410-H.P. Maybach diesel engines.

Fig. 109. — 300-H.P. DOBLE steam railcar.

instantaneous vaporisation and automatic regulation.

2 steam engines on the same bogie.

60 seats. Weight, 34 t. (33.5 Engl. tons).

Maximum speed : 90 km. (56 miles) an hour.

GERMANY.

Transmission.		Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order. t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*).	Kind of service.
Type.	Builders.								
				In service.					
				8 railcars with one 75-H.P. petrol engine.					
Mech.	N.A.G. and Gotha.	50 and 60 *(31 and 37.3)*	4	19 and 22 *(18.7 and 21.8)*	Rev. Trailer	45	1924 1925	...	Local.
				10 railcars of various designs, with one 100-H.P. petrol engine.					
Mech.	Various.	60 and 65 *(37.3 and 40.4)*	4	12-20 *(11.8-19.7)*	Rev. Trailer	45	1925 1926 1933	...	Local.
				3 railcars with one 120-H.P. Vomag C.E.H. petrol engine.					
Mech.	T.A.G.	65 *(40.4)*	4	13.7 *(13.5)*	Rev. Trailer	46	1932	...	...
				5 railcars with one 150-H.P. Deutsche Werke (Kiel) petrol engine.					
Mech.	T.A.G.	60 *(37.3)*	8	36 and 29 *(35.4 and 28.5)*	Rev. Trailer	70 and 50	1926 1931	...	...

Transmission.		Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*).	Kind of service.
Type.	Builders.								
3 railcars of various designs. with two 75-H.P. N.A.G. petrol engines (2 made up of 2 short coaches coupled together).									
Mech.	N.A.G.	60 *(37.3)*	8	37.4 and 30.8 *(36.8 and 30.3)*	Rev. Trailer	81 and 56	1926	...	...
9 railcars of various designs with two 100-H.P. Büssing petrol engines.									
Mech.	Zahnradfabrik, Friedrichshafen.	70 *(43.5)*	8	41.5 and 47 *(40.9 and 46.3)*	Rev. Trailer	56 and 72	1927 and 1929	...	...
20 Bautzen Waggonfabrik railcars with one 120-H.P. Daimler diesel engine (*).									
Mech.	T.A.G.	72 *(44.7)*	4	14.5 *(14.3)*	Rev. Trailer	40	1933 and 1934	...	Local.
3 Wegmann railcars with one 150-H.P. M.A.N. diesel engine.									
Mech.	Mylius.	85 *(52.8)*	4	23.9 *(23.5)*	Rev. Trailer	42	1927	...	...
42 railcars with one 175-H.P. Maybach diesel engine (*).									
Mech.	Maybach.	65 and 80 *(40.4 and 50)*	8	41 and 29.5 *(40.4 and 29.1)*	Rev. Trailer	71 and 63	1926 to 1933	...	Local and fast local.
19 railcars with one 210-H.P. Maybach diesel engine.									
Mech.	Maybach.	80 *(50)*	8	30.5 *(30.1)*	Rev. Trailer	63	End of 1934	...	Fast local.
3 Wegmann double railcars with two 150-H.P. M.A.N. diesel engines.									
Mech.	Mylius.	85 *(52.8)*	4+4	47 *(46.3)*	Rev. Trailer	83	1928	...	Local.
2 railcars with one 120-H.P. Daimler diesel engine.									
Electr.	S.S.W. (Gebus).	65 *(40.4)*	4	15.5 *(15.3)*	Rev. Trailer	43	1932	...	Local.
10 railcars with one 150-H.P. M.A.N. diesel engine (*).									
Electr.	B.B.C.	70 *(43.5)*	4	17.1 *(16.8)*	Rev. Trailer	40	1934	...	Local.
6 railcars with one 300-H.P. diesel engine { *3 with M.W.M. engine. 3 with Daimler engine.*									
Electr.	A.E.G.	90 *(56)*	8	42.2 *(41.6)*	Rev. Trailer	66	1934	5 500 *(3 420)* in October.	Fast local.
21 railcars with one 410-H.P. Maybach diesel engine (*).									
Electr.	M.S.W. B.B.C. S.S.W.	100 and 110 *(62 and 68.4)*	8	52 and 43 *(51.2 and 42.4)*	Rev. Trailer	72	1933 and 1934	...	Fast local and express.

(*) *Note.* — Railcars marked (*) have been described in the text.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order. t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*).	Kind of service
1 railcar with one 420-H.P. M.A.N. diesel engine.									
Electr.	B.B.C.	100 *(62)*	8	43 *(42.4)*	Rev. Trailer	72	End of 1934	On trial.	Fast local and express.
1 fast Wumag railcar (Schnelltriebwagen) with two 410-H.P. Maybach diesel engines (*).									
Electr.	S.S.W. (Gebus)	160 *(100)*	12	77.4 *(76.1)*	Rev.	102	1933	...	Fast express.
1 Wegmann railcar with one 150-H.P. M.A.N. diesel engine.									
Hydr.	Trilok.	*70 (43.5)*	4	23.5 *(23.2)*	Rev. Trailer	42	1927	On trial.	...
1 Doble steam railcar with two 150-H.P. engines (*).									
...	...	90 *(56)*	8	34 *(33.5)*	Rev. Trailer	70	1934	On trial.	...
Under construction.									
30 diesel-engined railcars { *9 with 120-H.P. engine. 20 with 150-H.P. engine. 1 with 180-H.P. engine.*									
Mech.	T.A.G.	75 *(46.6)*	4	15 *(14.8)*	Rev. Trailer	42	...	...	...
30 diesel-engined railcars { *28 with 210-H.P. engine. 2 with 300-H.P. engine.*									
Mech.	Maybach T.A.G. Mylius.	80 *(50)*	8	31 *(30.5)*	Rev. Trailer	66	...	...	...
116 diesel-engined railcars { *10 with 300-H.P. engine. 102 with 410 or 420-H.P. engine. 4 with 560-H.P. M.A.N. supercharged engine.*									
Electr.	A.E.G. S.S.W. B.B.C.	90-100 *(56-62)*	8	43 *(42.7)*	Rev. Trailer	72	...	...	...
15 railcars { *13 twin units with two 410-H.P. Maybach diesel engines. 2 triplets with two 600-H.P. Maybach diesel engines.*									
Electr.	A.E.G. S.S.W.	160 *(100)*	12 and 16	...	Rev.	102 and 139	...	...	...
5 railcars { *2 with one 150-H.P. M.A.N. diesel engine. 3 with one 210-H.P. M.A.N. diesel engine.*									
Hydr.	Trilok and Voith.	75 *(46.6)*	4	...	Rev. Trailer	42	...	...	...
4 railcars { *2 with one 280-H.P. M.A.N. diesel engine. 2 with one 420-H.P. M.A.N. diesel engine.*									
Hydr.	Voith.	90 and 110 *(56 and 68.3)*	8	...	Rev.	72	...	...	...

(*) *Note.* — Railcars marked (*) have been described in the text.

Transmission.		Maximum speed on the level km. (*miles*).	Number of wheels	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*).	Kind of service.
Type.	Builders.								
3 triple-unit railcars with two 600-H.P. Maybach diesel engines.									
Hydr.	Voith.	160 *(100)*	16	...	Rev.	...	...	...	...
2 steam railcars with one 100-H.P. Doble engine.									
...	...	65 *(40.4)*	4	...	Rev. Trailer	...	...	...	...
7 steam railcars with two 100-H.P. Doble engines (*).									
...	...	90 *(56)*	8	...	Rev.	60	...	...	...

(*) *Note.* — Railcars marked (*) have been described in the text.

Austria.

The Austrian Federal Railways at the present time have 52 railcars in service :

— 30 with petrol engines, 22 with diesel engines;

— 18 with mechanical transmission, 24 with electric transmission and six with hydraulic transmission.

They have no railcars on trial or under construction.

« *Maschinen u. Waggonbaufabrik A. G.* » *(Wien-Simmering) eight-wheeled railcar with one 160-*H.P. *diesel engine* (10 in service) (fig. 110).

— One 160 H.P. 8-cylinder Simmering diesel engine.

— Electric transmissions of various designs.

— 2 driving compartments.

Fig. 110. — SIMMERING railcar, with one 160-H.P. Simmering diesel engine.

— 64 seats. Weight, 32 t. (31.5 Engl. tons).

— Maximum speed : 80 km. (50 miles) an hour.

Austro-Daimler four-wheeled railcar with two 80-H.P. petrol engines (6 units in service).

— 2 Austro-Daimler petrol engines, 80-H.P. at 3 000 r.p.m. (6 cylinders).

— Austro-Voith hydraulic transmission with electro-pneumatic control.

— 2 driving compartments.

— 45 seats. Weight, 10.5 t. (10.3 Engl. tons).

— Maximum speed : 105 km. (65.2 miles) an hour.

Austro-Daimler eight-wheeled railcar with two 80-H.P. Austro-Daimler petrol engines (4 in service) (fig. 111).

— Two Austro-Daimler petrol engines, 80-H.P. at 3 000 r.p.m. (6 cylinders).

— Austro-Voith hydraulic transmission with electro-pneumatic control.

— 2 driving compartments.

— 74 seats. Weight, 19.0 t. (18.7 Engl. tons).

— Maximum speed : 100 km. (62 miles) an hour.

Oil-hydraulic brake; electro-magnetic brake.

Fig. 111. — AUSTRO-DAIMLER railcar with two 80-H.P. Austro-Daimler petrol engines.

AUSTRIA.

Transmission.		Maximum speed on the level km. (*miles*).	Number of wheels	Weight empty, in working order t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (1-1-33 to 1-10-33)	Kind of service.
Type.	Builders.								
In service.									
2 railcars with one 50-H.P. and 75-H.P. petrol engine.									
Mech.	Various.	40 and 50 *(25 and 31)*	4	14 *(13.8)*	Rev. Trailer	50	1924 1925	35 000 *(21 750)*	Local.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (1-1-33 to 1-10-33)	Kind of service.
3 railcars of various designs with one 100-H.P. petrol engine.									
Mech.	Various.	50 *(31)*	4	20 and 22 *(19.7 and 21.6)*	Rev. Trailer	50 to 60	1927	28 000 to 40 000 *(17 400 to 25 000)*	Local.
2 railcars of different designs with one 100-H.P. petrol engine.									
Mech.	Various.	40 and 55 *(25 and 34)*	8	18 and 27 *(17.7 and 26.6)*	Rev. Trailer	55 and 70	1925 1929	13 000 to 26 000 *(8 080 to 16 160)*	Local.
5 railcars of various designs with one 150-H.P. petrol engine.									
Mech.	Various.	50 to 60 *(31 to 37.3)*	8	27 to 33 *(26.6 to 32.5)*	Rev. Trailer	76 to 82	1926 1927	40 000 *(25 000)*	Local.
1 Wien railcar with two 60-H.P. petrol engines.									
Mech.	Fross-Büssing, Vienna.	50 *(31)*	4	21 *(20.7)*	Rev. Trailer	58	1927	36 000 *(22 370)*	Local.
1 Grazer Waggonbau und Maschinenfabrik A.G. rail motor van with one 200-H.P. Grazer diesel engine.									
Electr.	A.E.G.	45 *(28)*	6	39 *(38.4)*	Rev. Trailer	...	1927	21 000 *(13 050)*	Local.
1 Maschinen- und Waggonfabrik A.G. (Simmering, Vienna) railcar with one 100-H.P. petrol engine.									
Electr.	Deutsche. Werke, Kiel.	40 *(25)*	4	24 *(23.6)*	Rev. Trailer	55	1930	29 000 *(18 000)*	Local.
1 Wiener Lokomotivfabrik A.G. (Floridsdorf, Vienna) rail motor van with one S.E.G. (Vienna) 120-H.P. petrol engine.									
Electr.	Brown-Boveri.	40 *(25)*	4	12 *(11.8)*	Rev. Trailer	...	1930	22 000 *(13 700)*	Local.
1 Grazer Waggonbau u. Maschinenfabrik A.G. rail motor van with one 200-H.P. diesel engine									
Electr.	Siemens.	35 *(21.7)*	8	34 *(33.5)*	Rev.	...	1930	12 000 *(7 450)*	Local.
10 Maschinen- u. Waggonbaufabrik A.G. (Simmering, Vienna) railcar with one 160-H.P. diesel engine (*).									
Electr.	Various.	80 *(50)*	8	32 *(31.5)*	Rev. Trailer	64	1933	30 000 *(18 650)*	Fast local.
4 Perl Automobilfabrik A.G. (Liesing) railcars with one 85-H.P. petrol engine.									
Mech.	Perl.	45 *(28)*	4	6.4 *(6.3)*	Rev. Trailer	27	1933	25 000 *(15 550)*	Local.
1 Austro-Daimler railcar with one 80-H.P. Austro-Daimler engine.									
Mech.	Austro-Daimler.	100 *(62)*	4	6.2 *(6.1)*	Rev. Trailer	24	1932	55 000 *(34 200)*	Fast local.

Transmission.		Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order. t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (1-1-33 to 1-10-33).	Kind of service.
Type.	Builders.								
10 Grazer Waggonbau- u. Maschinenfabrik A.G. (Graz) rail motor vans with one 300-H.P. Grazer diesel engine.									
Electr.	Various.	65 *(40.4)*	4	27 *(26.6)*	Rev. Trailer	...	1933	4 000 *(2 500)*	Local.
6 Austro-Daimler railcars with two 80-H.P. Austro-Daimler petrol engines (*).									
Hydr.	Austro-Daimler.	105 *(65.2)*	4	10.5 *(10.3)*	Rev. Trailer	45	1933	10 061 *(6 125)*	Fast local.
4 Austro-Daimler railcars with two 80-H.P. Austro-Daimler petrol engines (*).									
Hydr.	Austro-Daimler.	100 *(62)*	8	19 *(18.7)*	Rev. No trail.	74	1933	...	...

(*) *Note.* — Railcars marked (*) have been described in the text.

Belgium.

The Belgian National Railways Company at the present time operates 31 railcars, i. e. :

— 24 with diesel engine and mechanical transmission,

— 3 with diesel engine and electric transmission,

— 4 steam railcars (3 Sentinel, 1 Birmingham).

This Company has, furthermore, 12 railcars under construction :

— 3 with diesel engine and mechanical transmission;

— 8 with diesel engine and electric transmission;

— 1 steam railcar.

All these railcars are reversible and have 2 driving compartments.

E. V. A. Maybach 2-bogie railcar with one 175-H.P. diesel engine (3 in service).

— 1 Maybach diesel engine, 175-H.P. at 1 400 r.p.m. (6 cylinders).

— 92 seats. Weight, 38 t. (37.4 Engl. tons).

Prototype of the « La Brugeoise » railcar described below.

« *La Brugeoise* » *2-bogie railcar with one 175-H.P. diesel engine* (14 in service).

— One Maybach diesel engine, 175-H.P. at 1 400 r.p.m. (6 cylinders).

— 4-stroke, compressed-air injection.

— Radiator carried below the underframe, behind the driving bogie.

— Maybach mechanical transmission.

— Maybach constant-mesh gear box, oil pressure controlled, driving a jack shaft driving in turn the 2 axles of the driving bogie by outside connecting rods.

— 104 seats. Weight : 32 t. (31.5 Engl. tons).

— Heating by « Ideal Classic » boiler and hot water pipes.

— Maximum speed : 80 km. (50 miles) an hour.

— Gas-oil consumption : 350 gr./km. (1.242 lb. per mile) on the level.

Sentinel steam railcars on 2 bogies (3 in service) (fig. 112).

— 100-H.P. at 500 r.p.m.

— 62 seats (1st and 2nd class).

— Maximum speed : 85 km. (52.8 miles) an hour. Weight : 34.5 t. (33.9 Engl. tons).

The Sentinel steam rail motor cars

are similar to those used on the London & North Eastern Railway.

As the Sentinel steam railcars and the E.V.A. Maybach railcars have approximately the same average mileage to their credit (about 400 000 km. = 250 000 miles), it is interesting to compare the working costs of these two types of railcars during the years 1932, 1933, and 1934.

	Sentinel, 100 H.P., steam.			E.V.A. Maybach, 175 H.P.		
Number of vehicles	3			3		
Total average mileage	433 000 km. *(269 060 miles).*			392 000 km. *(244 150 miles).*		
	1932	*1933*	*1934*	*1932*	*1933*	*1934*
Average daily mileage	295 km. *(183.3 miles)*	372 km. *(237.4 miles)*	407 km. *(252.9 miles)*	299 km. *(185.8 miles)*	303 km. *(188.3 miles)*	265 km. *(164.7 miles)*
Consumption per km. (per mile).						
Fuel-oil	...	...	...	0.346 kgr. *(1.228 lb.)*	0.406 kgr. *(1.440 lb.)*	0.445 kgr. *(1.579 lb.)*
Coal	4.1 kgr. *(14.54 lb.)*	4.139 kgr. *(14.68 lb.)*	4.041 kgr. *(14.34 lb.)*	...	...	...
Lubricating oil. cylinders	...	6 gr. *(0.34 oz.)*	...	...	17 gr. *(0.60 oz.)*	...
Lubricating oil. casing	...	3 gr. *(0.17 oz.)*	...	...	...	...
Lubricating oil. motion	...	5 gr. *(0.28 oz.)*	...	...	5 gr. *(0.18 oz.)*	...
Working costs per km. (per mile) in Belgian francs.						
Fuel	0.52 *(0.837)*			0.16 *(0.26)*		
Water	0.01 *(0.016)*			...		
Lubricant	0.09 *(0.145)*	1.76 *(2.83)*	1.58 *(2.54)*	0.09 *(0.14)*	0.81 *(1.30)*	0.79 *(1.27)*
Train staff (including general shed costs)	1.42 *(2.285)*			0.58 *(0.93)*		
Preparation costs (shed work).	0.10 *(0.161)*	0.12 *(0.19)*	0.45 *(0.72)*	0.08 *(0.13)*	0.06 *(0.10)*	0.07 *(0.11)*
Maintenance and repairs	0.44 *(0.708)*	0.49 *(0.79)*	0.16 *(0.26)*	0.95 *(1.53)*	1.68 *(2.70)*	1.28 *(2.06)*
	2.58 *(4.152)*	2.37 *(3.81)*	2.19 *(3.52)*	1.88 *(2.99)*	2.55 *(4.10)*	2.14 *(3.44)*

(The operating costs given above do not include the amortisation of the rail motor cars).

This table shows that, after a long mileage, the steam railcar appears to be better than the diesel as regards maintenance and repair costs.

The saving obtained in the case of the diesel by the use of one man only to drive it is absorbed by the additional cost of maintenance and repairs.

It must be pointed out however that, according to the latest information received, the Sentinel railcars will have to undergo heavy repairs which will increase their cost by the additional expenditure involved, whereas such expenditure is already included in the cost of the diesel railcars.

Birmingham steam railcar on 2 bogies
(one vehicle in service).

— 175 H.P., at 600 r.p.m.

— One bogie carries both the boiler which is fitted transversely to the track, and the engine.

— 82 seats.

— Maximum speed : 70 km. (43.5 miles) an hour.

This first vehicle was put into service in 1933.

Fig. 112. — 100-H.P. SENTINEL steam railcar.

*A.S.E.A. 2-bogie railcar with one 200-*H.P. *diesel engine* (one vehicle in service).

— 1 Burmeister & Wain diesel engine, 200 H.P. at 850 r.p.m., 2-stroke, 6 cylinders, mechanical injection.

— Engine fitted in the body.

— Radiators on the roof, with fans.

— A.S.E.A. electrical transmission.

— Two nose-suspended traction motors on the same bogie.

— 80 seats. Weight : 44 t. (43.3 Engl. tons).

— Maximum speed : 80 km. (50 miles) an hour.

Heating by means of radiators making use of the engine cooling water.

*Ganz four-wheeled railcar with one 120/150-*H.P. diesel engine (5 in service).

— 1 Ganz diesel engine, 120/150-H.P.

— 60 seats.

— Maximum speed : 72 km. (44.7 miles) an hour.

« *La Brugeoise* » *3-bogie twin railcar with one 410-*H.P. *diesel engine* (1 set in service) (fig. 113).

— One Maybach diesel engine, 410 H.P. at 1 400 r.p.m.

— 2 bodies carried on three bogies.

— Gebus electric transmission.

— One of the outer bogies carries the diesel engine and the generator; the other outer one is a carrying bogie.

Fig. 113. — La Brugeoise twin railcar with one 410-h.p. diesel engine.

— The middle bogie carries the two traction motors.

— 185 seats. Weight : 70 t. (68.9 Engl. tons).

— Maximum speed : 120 km. (75 miles) an hour.

The twin units are all-metal. They include 2nd and 3rd-class, compartments. The interior decoration is strikingly artistic, veneered panels of moiré bubinga having been used in the 2nd-class compartments, and dark limba veneered panels in the 3rd class.

A small saloon fitted with folding-up seats has been arranged over the middle bogie, through which passengers pass from one unit to the other.

Triplet railcars on 4 bogies, with two 400 h.p. (approx.) diesel engine (8 sets under construction).

— Two diesel engines of various designs (Maybach, 410 h.p. — Carels-Ganz, 380 h.p. — Mercedez-Benz, 450 h.p — Frichs, 400 h.p.).

— 3 bodies supported on 4 bogies.

— Electric transmission.

— The outer bogies carry the engines and generators; the inner bogies carry the traction motors.

— 229 seats, 2nd and 3rd-class. Weight, 118 t. (116 Engl. tons).

— Maximum speed : 140 km. (87 miles) an hour.

BELGIUM.

Transmission.		Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order. t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (1st Jan. 1935).	Kind of service.
Type.	Builders.								
In service.									
3 E.V.A. railcars with one 175-H.P. Maybach diesel engine (*).									
Mech.	Maybach.	70 *(43.5)*	8	38 *(37.4)*	Rev. No trail.	92	1930	302 000 *(211 140)*	Fast local.
14 « Société Anonyme La Brugeoise » railcars with one 175-H.P. Maybach diesel engine (*).									
Mech.	Maybach.	80 *(50)*	8	32 *(31.5)*	Rev. No trail.	104	1933	138 000 *(85 750)*	Fast local.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (1st Jan. 1935).	Kind of service.
3 Sentinel railcars with one 100-H.P. Sentinel steam engine (*).									
...	...	85 *(52.8)*	8	34.5 *(33.9)*	Rev. No trail.	62	1930	433 000 *(269 000)*	Fast local.
1 Birmingham railcar with one 175-H.P. Yorkshire steam engine (*).									
...	...	70 *(43.5)*	8	43.7 *(43.0)*	Rev. No trail.	82	1933	102 647 *(63 780)*	Fast local.
1 A.S.E.A. railcar with one 200-H.P. Burmeister & Wain diesel engine (*).									
Electr.	A.S.E.A.	80 *(50)*	8	44 *(43.3)*	Rev. No trail.	74	1932	277 579 *(172 482)*	Fast local.
5 Ganz railcars with one 120/150 H.P. Ganz diesel engine (*).									
Mech.	Ganz.	72 *(44.7)*	4	15.5 *(15.2)*	Rev. No trail.	60	1934	46 279 *(28 757)*	Local.
1 « La Brugeoise » double railcar with one 410-H.P. Maybach diesel engine (*).									
Electr.	Gebus.	120 *(75)*	12	70 *(68.9)*	Rev. No trail. Twins.	185	1934	60 914 *(37 850)*	Express.
1 « La Dyle » railcar with one 140-H.P. M.A.N. diesel engine.									
Mech.	T.A.G. (Berlin).	80 *(50)*	2	16.5 *(16.2)*	Rev. No trail.	60	1934	25 411 *(15 790)*	Fast local.
1 « La Brugeoise » railcar with one 210-H.P. Maybach diesel engine.									
Mech.	Maybach.	80 *(50)*	8	30 *(29.5)*	Rev. No trail.	104	1934	39 847 *(24 760)*	Fast local.
1 « La Brugeoise » railcar with one 210-H.P. Maybach diesel engine.									
Electr.	A.C.E.C. (Charleroi).	80 *(50)*	8	30 *(29.5)*	Rev. No trail.	104	1934	10 420 *(6 475)*	Fast local.
On trial or under construction.									
One 250-H.P. Sentinel steam railcar.									
...	...	80 *(50)*	8	40 *(39.4)*	Rev. No trail.	70	...	...	...
1 « Forges et Fonderies de Haine-St.Pierre » railcar, with one 330-H.P. Mercedes-Benz diesel engine.									
Mech.	Winterthur.	90 *(56)*	8	30 *(29.5)*	Rev. No trail.	70	...	...	...
1 « Baume et Marpent » railcar with one 320-H.P. Carels-Ganz diesel engine.									
Mech.	Winterthur.	90 *(56)*	8	31 *(30.5)*	Rev. No trail.	70	...	...	...
1 S.E.M. railcar with one 220-H.P. Carels-Ganz diesel engine.									
Mech.	Ganz.	80 *(50)*	8	25 *(24.6)*	Rev. No trail.	104	...	...	...

(*) *Note.* — Railcars marked (*) have been described in the text.

Transmission.		Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order. t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (1st Jan. 1935).	Kind of service.
Type.	Builders.								
3 « La Brugeoise » triplet railcars with two 410-H.P. Maybach diesel engines (*).									
lectr.	A.C.E.C. (Charleroi).	140 *(87)*	16	118 *(116)*	Rev. Trailer.	229	...	...	...
5 « Baume et Marpent » triplet railcars (*)		*3 with two 380-H.P. Carels diesel engines. 1 with two 450-H.P. Mercedes-Benz diesel engines. 1 with two 400-H.P. Frichs diesel engines.*							
lectr.	Various.	140 *(87)*	16	118 *(116)*	Rev. Trailer.	229	...	...	...

Denmark.

Denmark has been gradually developing its railcar services since 1925, and its stock now consists of 76 such vehicles, including 56 petrol-engined, and 20 diesel-engined railcars.

The first vehicles put into service had a single driving compartment, and consequently could only run in one direction. As a result, they were often used in pairs. Sometimes one, two or even three trailers were put between two railcars in order to make up a small train with a driving unit at each end. As the two driving units were not connected together, a single engine was used to haul the train.

The first railcars equipped with Diesel engines date from 1928. From the beginning, the designers (Frichs, of Aarhus) placed the engine on one of the bogies and used electric transmission. The first vehicles gave rise to some difficulties before they were perfected, but in 1932 Messrs. Frichs brought out 4 railcars with 220-H.P. diesel engine, which gave immediate satisfaction.

4 triplet railcars each with four 250-H.P. Frichs diesel engines and electrical transmission are now being built in Denmark.

8-wheeled Odense railcars with two 110-H.P. petrol engines (16 in service).

— Two 100-H.P. Continental petrol engines.

— Thrige Odense electric transmission.

— The two engines and the two generators are carried on one of the bogies, and the two traction motors on the other.

— Can run in either direction. A driving compartment at each end.

— 70 seats. Weight : 42 t. (41.3 Engl. tons).

— Maximum speed : 80 km. (50 miles) an hour.

— Heating by an auxiliary coke boiler.

12-wheeled Frichs railcars with one 220-H.P. Frichs diesel engine (4 in service).

— One 220-H.P. Frichs diesel engine.

— Titan (Copenhague) electric transmission (Léonard type).

— One bogie carries the diesel engine and the generator, the other the two traction motors.

— Can haul one or two trailers.

— 70 seats. Weight : 55 t. (54.1 Engl. tons).

— Maximum speed : 100 km. (62 miles) an hour.

— Independent heating by means of hot water pipes from a coke boiler.

12-wheeled Frichs railcars with two 220-H.P. Frichs diesel engines (10 in service).

— Two 220-H.P. Frichs diesel engines — 6 cylinders.

— Titan electric transmission.

— Two 6-wheeled bogies, one fig. 75 carrying the two diesel engines and the two generators, the other the two traction motors driving the two outer axles of the bogie.

— 70 seats. Weight : 56 t. (55.1 Engl. tons).

— Can haul one or two trailers.

— Maximum speed : 120 km. (75 miles) an hour.

— Cooled by radiators on the roof.

The first of these rail motor cars was tested in January 1934, and the starting curve on the level (fig. 114) was obtained with a total weight of 56 t. (55.1 Engl. tons) and with the engines developing a power of 445 H.P.

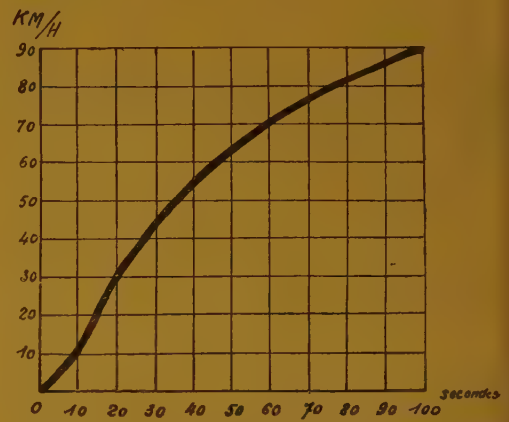


Fig. 114. — Starting curve of railcar with 440/480 H.P.-Frichs diesel engine.

DENMARK.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (31-12-1933).	Kind of service.
In service.									
38 Odense railcars with one 80-H.P. Continental petrol engine.									
Mech.	Forenede Automobil Fabriker, Odense.	70 *(43.5)*	4	14 *(13.8)*	Rev. Twins. Trailer.	33	1926 1927 1928 1929	400 000 *(250 000)*	Local.
2 Odense railcars with two 80-H.P. Continental petrol engines.									
Mech.	Forenede Automobil Fabriker, Odense.	55 *(34.2)*	6	19 *(18.7)*	Rev. Twins. Trailer.	50	1926	300 000 *(186 000)*	Local.
16 Odense railcars with two 100-H.P. Continental petrol engines (*).									
Electr.	Thrige, Odense.	80 *(50)*	8	42 *(41.3)*	Rev. Trailer.	60-70	1928 1930	200 000 to 500 000 *(124 000 to 310 000)*	Fast local. Express.

(*) *Note.* — Railcars marked (*) have been described in the text.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order. t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (31-12-1933).	Kind of service.
		6 Frichs railcars with one 160-H.P. Frichs diesel engine.							
Electr.	Siemens.	80 *(50)*	8	44 *(43.3)*	Rev. Trailer.	60	1928	300 000 *(186 000)*	Local. Express.
		4 Frichs railcars with one 220-H.P. Frichs diesel engine (*).							
Electr.	Titan.	100 *(62)*	12	55 *(54.1)*	Rev. Trailer.	70	1932	70 000 *(43 500)*	Fast local.
		10 Frichs railcars with two 220-H.P. Frichs diesel engines (*).							
Electr.	Titan.	120 *(75)*	12	56 *(55.1)*	Rev. Trailer.	70	1934	...	Fast local. Express.
		Under construction.							
		4 Frichs triplet railcars with four 250-H.P. Frichs diesel engines.							
Electr.	Titan.	120 *(75)*	16	118 *(116)*	Rev. Trailer.	156	...	...	Express.

Spain.

Norte (Northern of Spain) Railway.

The Norte has now under construction 14 railcars of various designs, all diesel-engined.

8-wheeled Geathom railcars with one 400-H.P. diesel engine (3 under construction).

— One 400-H.P. Ganz diesel engine.

— Electric transmission, Lemp system.

— 2 driving compartments.

— 102 seats. Weight : 47.5 t. (46.8 Engl. tons).

— Maximum speed : 110 km. (68.4 miles) an hour.

Norte (Northern of Spain) Railway.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels	Weight empty, in working order. t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*).	Kind of service.
		Under construction.							
		3 Geathom railcars, with one 400-H.P. Ganz diesel engine (*).							
Electr.	Lemp.	110 *(68.4)*	8	47.5 *(46.8)*	Rev.	102	...	...	...
		2 Ganz railcars, with one 150-H.P. Ganz diesel engine.							
Mech.	Ganz.	95 *(59.0)*	4	16.5 *(16.2)*	Rev.	45	...	...	...

Transmission.		Maximum speed on the level km. (*miles*).	Number of wheels	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*).	Kind of service.
Type.	Builders.								
7 Carde & Escariaza railcars with one 150-H.P. Maybach diesel engine.									
Mech.	Mylius.	...	4	12 (*11.8*)	...	52	...	...	...
2 Bilbao Ship Yards railcars with one 95-H.P. Beardmore diesel engine.									
Mech.	S.O.M.U.A.	90 (*56*)	4	11 (*10.8*)	Not. rev.	40	...	...	...

Madrid-Saragossa-Alicante Railway.

This Railway has at present 5 diesel-engined railcars in service.

Transmission.		Maximum speed on the level km. (*miles*).	Number of wheels	Weight empty, n working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*).	Kind of service.
Type.	Builders.								
In service.									
4 railcars with one 410-H.P. Maybach diesel engine.									
Electr.	Brown-Boveri.	70 (*43.5*)	8	45 (*44.5*)	Rev. Trailer.	80	...	...	...
1 railcar with one 250-H.P. Burmeister & Wain diesel engine.									
Electr.	...	...	8	36 (*35.5*)	Rev. Trailer.	68	...	...	...

Central de Aragon Railway.

The Central de Aragon Railway has now in service two 4-wheeled railcars with one 150-H.P. Deutz diesel engine and mechanical transmission of the Mylius system; they weigh 30 t. (29.5 Engl. tons) and seat 80 passengers.

Finland.

The Finnish State Railways have 11 railcars, two of which have petrol engines and are used in local services. All these vehicles can run in either direction, and can haul one or several trailers.

All the engines are four-stroke (6 cylinders). The radiators are in the roof.

In the event of intense cold, the radiators can be protected by revolving shutters or by felt covers; some of the radiators can be cut out.

8-wheeled railcar with one 150-H.P. diesel engine (5 in service) (fig. 115).

— One 150-H.P., 7-cylinder M.A.N. diesel engine.

— A.E.G. electrical transmission.

— 2 driving compartments.

— 60 seats. Weight : 46.5 t. (45.8 Engl. tons).

Fig. 115. — 8-wheeled railcar, with one 150-H.P. M.A.N. diesel engine, Finnish State Railways.

FINLAND.

Transmission.		Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (1st Jan. 1934).	Kind of service.
Type.	Builders.								
In service.									
2 N.A.G. railcars with one 75-H.P. N.A.G. petrol engine.									
Mech.	N.A.G.	45 *(28)*	4	20.3 *(20.0)*	Rev. Trailer.	42	1928	226 200 *(140 560)*	Local.
3 railcars with one 90-H.P. Atlas diesel engine.									
Electr.	A.S.E.A.	56 *(34.8)*	8	33.2 *(32.7)*	Rev. Trailer.	50	1928-1930	295 700 *(183 740)*	Local.
5 railcars with one 150-H.P. M.A.N. diesel engine (*).									
Electr.	A.E.G.	75 *(46.6)*	8	46.5 *(45.8)*	Rev. Trailer.	60	1933	62 195 *(38 650)*	Local.
1 railcar with 170-H.P. Atlas diesel engine.									
Electr.	B.B.C.	75 *(46.6)*	8	16.1 *(15.8)*	Rev. Trailer.	60	1934	21 964 *(13 648)* (1st Jan. 1935).	Local.

(*) *Note.* — Railcars marked (*) have been described in the text.

France.

On the 1st January 1935, the French Railways owned :

214 railcars in service, and

249 on trial or under construction.

They consider that the railcar problem is very interesting as regards the future of the railway, and they tried a great many of the original designs; extensive tests were carried out before a selection was made of the types to be finally adopted.

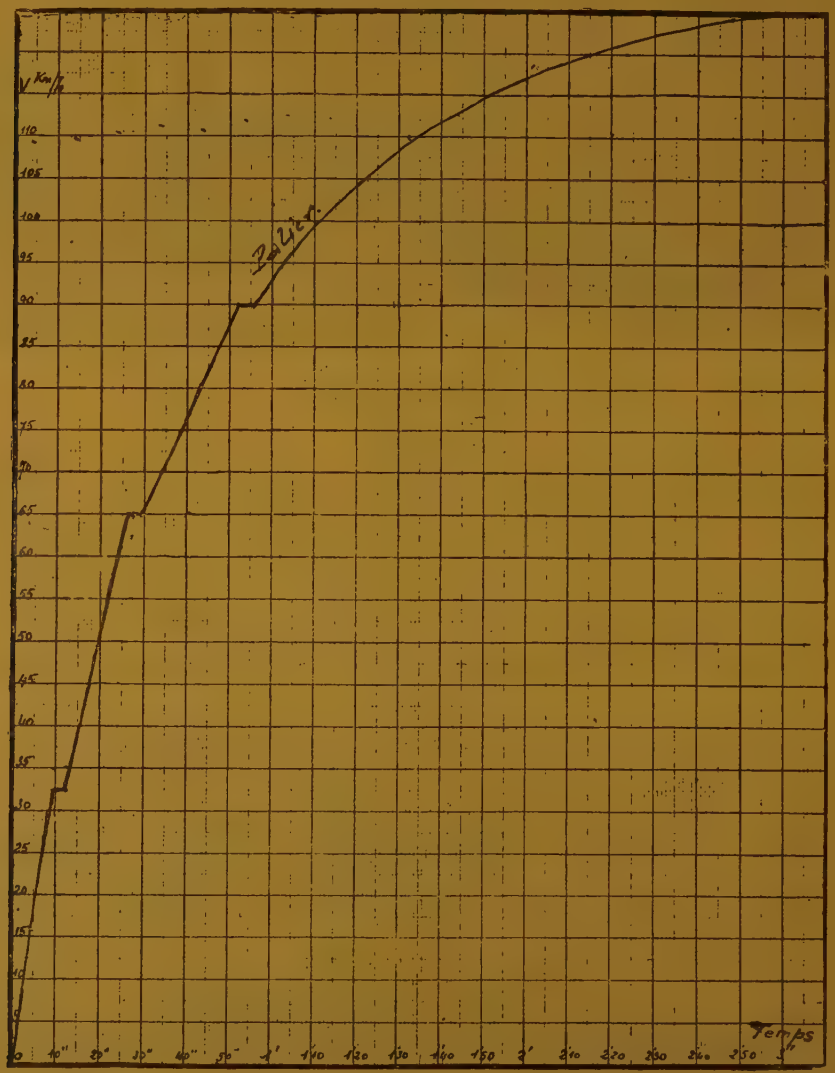


Fig. 116. — Starting curve of 32-seater MICHELINE under full load.

Note : Palier = On the level.

Notwithstanding the lengthy experimental period, a certain number of orders were issued for railcars built on mass-production lines.

Messrs. MICHELIN are building on mass-production lines 36 and 56-seaters, the comfort and acceleration capability of which are much appreciated by the public; twenty-one 36-seater railcars are now in service, 7 are being built; 5 Michelines with 56 seats are in service and 18 under construction.

Messrs. RENAULT who have already supplied 93 bogie railcars to the French Railways, are building a further 29, and more orders are being prepared.

Messrs. DE DIETRICH received an order for 46 railcars, 35 of which have been delivered.

The « ACIÉRIES DU NORD » (A. D. N.), after experimenting with several prototypes, have perfected a 280-H.P. railcar with one driving bogie; the Paris-Orléans and Paris-Lyons-Mediterranean have ordered 16 of these vehicles. Furthermore, this firm grouped several builders with a view to the construction of a so-called « standard » 2-bogie railcar, 41 having been ordered by the Est, Nord and P. O.-Midi.

36-seater, 12-wheeled Michelines with one 220-H.P. petrol engine (21 in service, 7 on trial or under construction, State, Est and Nord.

— One Hispano V-type 12-cylinder petrol engine, 220-H.P. at 3 000 r.p.m., mechanical transmission, Panhard gear box, 4 speeds.

1 driving compartment which is raised above the vehicle so that it can run in either direction.

Two 6-wheeled bogies on pneumatic tyres.

36 seats. Weight, 7.5 t. (7.4 Engl. tons).

Maximum speed : 100 km. (62 miles) an hour.

Heating by circulating hot air heated by the engine cooling water.

Fig. 117. — 56-seater MICHELINE twin railcars.

Lockheed hydraulic brake.

Messrs. MICHELIN have also built a 32-seater Micheline, equipped with the same Hispano engine; this vehicle, the rear part of which is streamlined, can only be run in one direction. It has approximately the same length and weight as the 36-seater. Figure 116 shows its starting curve. Fully loaded it reaches the speed of 80 km. (50 miles) an hour in 42 seconds.

*56-seater 16-wheeled Michelines with one 220-*H.P. *petrol engine (fig. 117).*

(5 in service — 18 under construction: Est, State, Nord and P. O.-Midi Systems.)

— One 12-cylinder V-type Hispano petrol engine, 220 H.P. at 3 000 r.p.m.

— Mechanical transmission, 4 speeds.

— 1 raised driver's look-out from which the car is being driven in both directions.

— Two 8-wheeled bogies with pneumatic tyres.

— 56 seats. Weight, 8 t. (7.9 Engl. tons).

— Maximum speed : 105 km. (65.3 miles) an hour.

— Oleo - pneumatic Westinghouse - Lockeed brake.

The railcars under construction can be coupled up in pairs, each of them being driven by its own driver.

*8-wheeled Renault railcar with one 220- or 265-*H.P. *diesel engine (fig. 118).*

(122 units in service or on order for all the French Railways.)

— One 12-cylinder V-type Renault diesel engine, 220 or 265 H.P.

Fig. 118. — RENAULT railcar, with one 265-H.P. Renault diesel engine.

— Renault mechanical transmission, 4 speeds (fig. 30).

— Electro-pneumatic control, allowing of 2 units coupled up being driven by one man.

— 2 driving compartments.

— 56 to 70 seats. Weight, 27 t. (26.6 Engl. tons) approx.

— Maximum speed : 120 km. (75 miles) an hour.

— Compressed-air brake and electromagnetic brake.

— Heating by exhaust gases.

Double 12-wheeled Renault railcars, with two diesel engines, 265 H.P. *each (fig. 119).*

(1 set in service, 6 under construction : State and P.L.M.)

— 2 Renault diesel engines, 12 cylinders V-type, 265 H.P. at 1 500 r.p.m.

— Renault mechanical transmission with electro-pneumatic control.

— 2 driving compartments.

— 2 bodies supported on three 4-wheeled bogies.

— 100 seats. Weight, 56.5 t. (55.7 Engl. tons).

Fig. 119. — Double RENAULT railcar with two 265-H.P. Renault diesel engine.

— Maximum speed : 140 km. (87 miles) an hour.

— Compressed-air brake and electromagnetic brake.

8-wheeled de Dietrich railcars with two 100-H.P. diesel engines.

(10 in service, 36 on trial or under construction for most of the railways.)

— Two C.L.M. diesel engines, each 4 cylinders with opposed pistons, 100 H.P. at 1 500 r.p.m.

— Mechanical transmission, Mylius design, 4 speeds, with pneumatic control.

— 8 elastic wheels, L. B. system (fig. 64).

— Bogie shown in figure 72.

— 2 driving compartments.

— 75 seats. Weight, 23 t. (22.7 Engl. tons).

— Maximum speed : 100 km. (62 miles) an hour.

— Jourdain-Monneret-Lockheed oleopneumatic brake.

— Heating by independent oil-fired boiler.

So called « Standard » Aciéries du Nord 2-bogie railcar, with two diesel engines of 265 H.P.

(41 under construction for the Est, Nord and P.O.-Midi Systems.)

— 2 Renault diesel engines, 12 cylinders V-type, 265 H.P. at 1 500 r.p.m.

— Winterthur mechanical transmission.

2 driver's compartments.

— 60 seats. Weight, 38 t. (37.5 Engl. tons).

— Maximum speed : 120 km. (75 miles) an hour.

— This railcar will be suitable for main-line services as well as for traffic on secondary lines; thanks to its excess power, it will have quick acceleration and will be able to easily haul a trailer.

16-wheeled Bugatti railcar with four 200-H.P. petrol engines.

(20 units — 8 of which in service — for the State, P.L.M. and Alsace-Lorraine Rys.)

— 4 Royal Bugatti petrol engines, 200-H.P. at 2 500 r.p.m. (8 cylinders), grouped in a central cabin and placed at right angle to the longitudinal centre line of the vehicle (fig. 36).

— Each engine is fitted with a Daimler hydraulic clutch (fig. 37) and a bevel-pinioned reversing gear.

— Central raised driving compartment

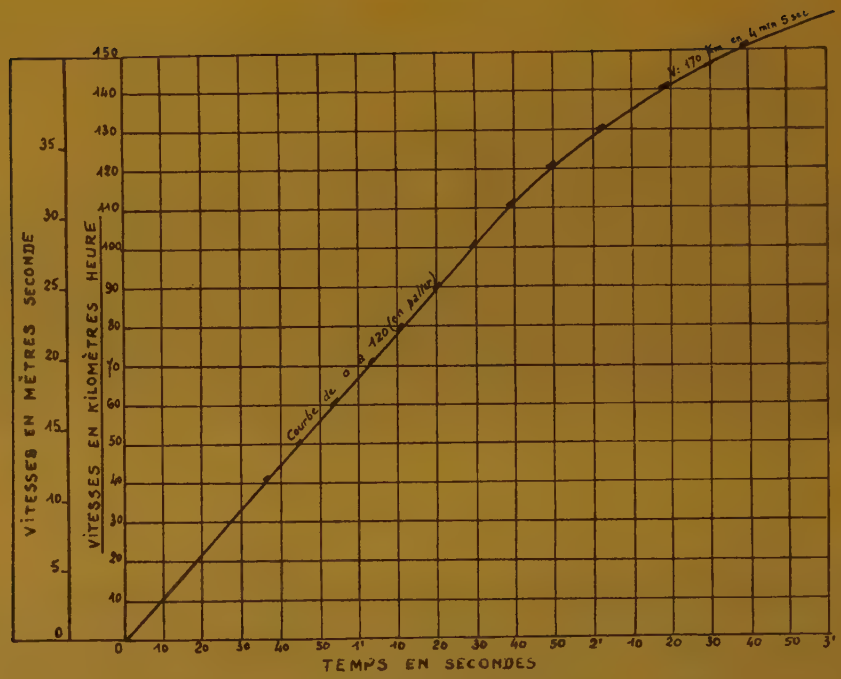

VITESSES EN MÈTRES SECONDE
VITESSES EN KILOMÈTRES HEURE
TEMPS EN SECONDES
Courbe de 0 à 120 (en palier)
V: 170 km en 4 min 5 sec.

Fig. 120. — Starting curve — under full load — of the 800-H.P. BUGATTI railcar, French State Railways.

Note: Vitesse en mètres seconde = Speed, metres per second. — Vitesse en kilomètres... = Speed, km. per hour. — Courbe de 0... = Curve from 0 to 120 km. (75 miles) on the level. — V : 170 km... = Speed : 105.6 miles an hour in 4 min. 5 sec. — Temps en secondes = Time in seconds.

from which the vehicle is driven in both directions.

— Two 8-wheeled bogies, 2 driving axles per bogie. Elastic wheels.

— 60 seats. Weight, 25 to 30 t. (24.6 to 29.5 Engl. tons).

— In the course of the trials, a speed of 190 km. (118.1 miles) was reached.

— Air brake and hand brake.

— The starting curve of this railcar is given in figure 120.

The Bugatti railcars of the P.L.M. have a trailer coupled up to them, thus forming a complete unit, which can be worked at high speeds in both running directions (fig. 121).

The Bugatti railcars of the State Rys. can take a Bugatti trailer offering 62 seats.

16-wheeled Bugatti railcar with two 200-H.P. petrol engines.

(23 under construction : Alsace-Lorraine, State and P.L.M.)

These railcars are similar to the preceding vehicles, but have only two 200-H.P. petrol engines.

24-wheeled Franco-Belge sets with two 410-H.P. diesel engines (fig. 122).

(2 sets in service, 8 under construction, Nord Ry.)

— Each set is made up of 3 units each supported on 2 bogies : 2 power units with one trailer between them.

Fig. 121. — Paris-Lyons and Mediterranean Railways' BUGATTI railcar, with four 200-H.P. Bugatti petrol engines, and its trailer.

Fig. 122. — FRANCO-BELGE three-coach set with two 410-H.P. Maybach diesel engines.

Fig. 123. — Pauline No. 2 railcar with one 80-h.p C.L.M. diesel engine.

— Each driving unit has a Maybach diesel engine, 410 h. p. at 1 400 r.p.m. direct-coupled to the generator, both being on the outer bogie of the set.

— Gebus electric transmission, modified by the « Franco-Belge ».

— 144 seats, 62 of which in the middle unit, weight 117 t. (114.1 Engl. tons).

— Maximum speed : 150 km. (93 miles) an hour.

— Heating by independent coke-fired boiler.

— Jourdain-Monneret-Lockheed brake (braking force proportional to the vehicle speed).

— Electro-magnetic brake for emergency stops in 600 yards and 24 seconds from a speed of 140 km. (87 miles) an hour running down a 1 in 200 gradient.

Pauline No. 2 (Entreprises industrielles Charentaises) railcar with four pairs of wheels and one 80-h.p. diesel engine (19 vehicles in service, 8 of them on the Midi Railway) (fig. 123).

— One C.L.M. diesel engine, 80 h.p at 1 500 r.p.m., 3 cylinders with opposed pistons; mechanical transmission with Minerva gear box giving 5 speeds.

— Two driving compartments.

— The whole of the underframe and body framing is made of duralumin.

— 50 seats. Weight, 10.2 t. (10 Engl. tons).

— Maximum speed, 90 km. (56 miles) an hour.

— Heating by the engine cooling water.

Fig. 124. — S.O.M.U.A. 6-wheeled articulated railcar with one 210-H.P. M.A.N. diesel engine.

— Charlestop brake, with hydraulic control.

6- or 8-wheeled S.O.M.U.A. railcars with one 210-H.P. or 280-H.P. diesel engine (fig. 124).

(Two six-wheeled railcars in service, State Rys.; eleven 8-wheeled cars on order for the P.L.M.)

— The 6-wheeled railcars have a M.A.N. engine, 210 H.P. at 1 400 r.p.m.

— The 8-wheeled railcars have a M.A.N. engine, 280 H.P. at 1 400 r.p.m.

— S.O.M.U.A. mechanical transmission.

— 75 seats. Weight, 29 t. (28.5 Engl. tons).

— Maximum speed : 90 km. (56 miles) an hour.

— The 6-wheeled railcars are made up of one 4-wheeled driving unit and a trailer supported at one end by the driving unit and at the other end on a third pair of wheels; the wheels are loose on fixed axles, no axle box guides being fitted.

4-wheeled railcars of the Compagnie Générale de Construction with one 150-H.P. diesel engine.

(8 units in service on the State und P. L. M.)

— One 6-cylinder M.A.N. Diesel engine, 150 H.P. at 1 500 r.p.m.

— One central driving compartment raised above the roof.

— Mechanical transmission, 4-speed gear box with sliding gears.

— 44 seats. Weight, 17.7 t. (17.4 Engl. tons).

— Maximum speed : 90 km. (56 miles) an hour.

* * *

Railcars on the Secondary and Colonial Railways.

The French secondary railways have many railcars in service and under construction.

Special mention must be made of those designed for the « Cie des Voies ferrées d'intérêt local », the railcars of the « Société Centrale de Chemins de fer et d'Entreprises »; those of the « Compagnie Générale de Construction de Batignolles-Châtillon »; the Brissonneau railcars with electrical transmission; the small A. Laborie railcar with pneumatic tyres; the battery-driven coaches of the Sud-Ouest Railway and the Renault railcars of the « Cie des Chemins de fer secondaires ».

The Algerian Railways have 8 railcars in service, and two under construction.

The Madagascar Railways have two 18-seater Michelines in operation for

express services between Tamatave and Tananarive.

The « Compagnie française de l'Indo-Chine et du Yunnan » has now 1 railcar in service (21-seater Micheline with one 110-H.P. Panhard petrol engine) and 5 railcars on order (3 Decauville units with two 140-H.P. Saurer diesel engines, and 2 Decauville railcars with one 140-H.P. Saurer diesel engine.

The Congo-Océan Railway has ordered some Billard rail motor cars, with Berliet engine, and two 12-seater Michelines.

For colonial metre-gauge lines, Messrs. MICHELIN have just designed a special Micheline seating 46 passengers and supported on two 8-wheeled bogies.

FRANCE.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (1st. Jan. 1935).	Kind of service.
In service.									
10 Michelines, 24 seats, with one 95-H.P. Panhard petrol engine. (Est, State, Nord, P.O.-Midi).									
Mech.	Panhard.	95 *(59)*	10	4.7 *(4.6)*	Not rev. No trail.	24	1932	168 000 *(104 400)*	Fast local.
21 Michelines, 36 seats, with one 220-H.P. Hispano petrol engine (*) (Est, State, Nord).									
Mech.	Panhard.	100 *(62)*	12	7.5 *(7.4)*	Rev. No trail.	36	1933-1934	60 000 *(37 300)*	Fast local.
5 Michelines, 56 seats, with one 220-H.P. Hispano petrol engine (*) (Est, State, P.O.-Midi).									
Mech.	...	100 *(62)*	16	8 *(7.9)*	Rev. No trail.	56	1934	40 000 *(25 000)*	Fast local.
14 Renault railcars with one 85-H.P. Renault diesel engine (State) (*).									
Mech.	Renault.	90 *(56)*	4	11 *(10.8)*	Not rev. No trail.	34	1930-31-32	130 000 *(80 780)*	Fast local. Interurban.
79 Renault railcars with one 220-H.P. or 265-H.P. Renault diesel engine. (All Railways) (*).									
Mech.	Renault.	120 *(75)*	8	27 *(26.6)*	Rev. No trail.	56	1933-1934	25 000 *(15 500)*	Fast local. Interurban.
1 Renault double railcar, with two 265-H.P. Renault diesel engines (State) (*).									
Mech.	Renault.	140 *(87)*	12	51 *(50.2)*	Rev. Trailer.	116	1934	28 000 *(17 400)*	Rapides.
6 Renault railcars with one 110-H.P. Renault diesel engine (State).									
Mech.	Renault.	90 *(56)*	4	9 *(8.9)*	Rev. No trail.	28	1934	27 000 *(16 780)*	Newspapers.
10 de Dietrich railcars with two 100-H.P. C.L.M. diesel engines (Als-Lorr.) (*).									
Mech.	Mylius.	100 *(62)*	8	23 *(22.6)*	Rev. No trail.	75	1933	10 000 *(6 200)*	Local.

(*) *Note.* — Railcars marked (*) have been described in the text.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, Km. (*miles*). (1st. Jan. 1935).	Kind of service.
2 A.D.N. railcars with one 170-H.P. M.A.N. diesel engine (P.L.M.) (*).									
Mech.	A.D.N.	100 *(62)*	8	33.6 *(33.1)*	Rev. No trail.	73	1933	100 000 *(62 000)*	Local.
2 A.D.N. railcars with one 170-H.P. M.A.N. diesel engine (P.O.) (*).									
Mech.	A.D.N.	120 *(75)*	8	31 *(30.6)*	Rev. No trail.	65	1934	61 000 *(37 900)*	Local.
2 A.D.N. railcars with one 250-H.P. M.A.N. diesel engine (Nord) (*).									
Electr.	1 A.S.E.A. 1 Jeumont.	100 *(62)*	8	30 *(29.5)*	Rev. No trail.	66	1934	32 000 *(20 000)*	Local.
2 A.D.N. railcars with one 280-H.P. M.A.N. diesel engine (State).									
Mech.	Winterthur.	120 *(75)*	8	36 *(35.4)*	Rev. No trail.	74	1934	17 000 *(10 560)*	Local. Interurban.
8 Bugatti railcars with four 200-H.P. petrol engines (State, 5—P.L.M., 3 with trailer) (*).									
Hydr.	Bugatti.	150 *(93)*	16 and 32	25 and 54 *(24.6 and 53.1)*	Rev. Trailer.	60 and 74	1933-1934	40 000 *(25 000)*	Rapides.
2 Franco-Belge articulated motor trains with two 410-H.P. Maybach diesel engines (Nord) (*).									
Electr.	Gebus (Franco-Belge).	150 *(93)*	24	117 *(115.8)*	Rev.	140	1934	60 000 *(37 300)*	Rapides.
5 Charentaises railcars with one 110-H.P. Peugeot-Junkers diesel engine (P.O.-Midi).									
Mech.	Minerva.	90 *(56)*	4	9 *(8.9)*	Rev. No trail.	45	1932-1934	20 000 *(12 400)*	Local.
19 Charentaises « Pauline 2 » railcars with one 80-H.P. Peugeot-Junkers diesel engine (*). *(Als-Lorr., State, P.L.M., P.O.-Midi).*									
Mech.	Minerva.	90 *(56)*	8	10 *(9.8)*	Rev. No trail.	50 to 60	1933-1934	76 000 *(47 225)*	Local.
2 Charentaises railcars with one 120-H.P. M.A.N. diesel engine (Est).									
Mech.	Minerva.	100 *(62)*	8	15 *(14.8)*	Rev. No trail.	61	1934	50 000 *(31 000)*	Local.
2 S.O.M.U.A. railcars with one 80-H.P. Peugeot-Junkers diesel engine (P.L.M.) (*).									
Mech.	S.O.M.U.A.	90 *(56)*	4	11.7 *(11.5)*	Not rev. No trail.	40	1933	36 000 *(22 370)*	Local.
2 S.O.M.U.A. railcars with one 210-H.P. M.A.N. diesel engine (State) (*).									
Mech.	S.O.M.U.A.	90 *(56)*	6	28.5 *(28.1)*	Rev. Trailer.	75	1934	18 000 *(11 185)*	Local.
8 « Compagnie Générale de Construction » railcars with one 150-H.P. or 120-H.P. M.A.N. diesel engine (P.L.M. and State) (*).									
Mech.	C^ie^ G.C.	90 *(56)*	4	17.7 *(17.4)*	Rev. No trail.	44	1933-1934	36 000 *(22 370)*	Local.

(*) *Note.* — Railcars marked (*) have been described in the text.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order. t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (1st. Jan. 1935).	Kind of service.
6 Baudet-Donon-Roussel railcars with one 110-H.P. Peugeot-Junkers diesel-engine (P.L.M., P.O.-Midi).									
Mech.	Glaenzer-Spicer. Cotal gear box.	90 *(56)*	4	12.5 *(12.3)*	Rev. Twins.	40	1934	21 000 *(13 050)*	Local.
2 Decauville railcars with two 140-H.P. Saurer diesel engines (Nord).									
Mech.	Winter-thur.	100 *(62)*	8	26 *(25.6)*	Rev. No trail.	64	1934	21 000 *(13 050)*	Local.
2 « C^{le} française de Matériel de Ch. de fer » railcars with one 140-H.P. Saurer diesel engine (P.L.M.).									
Mech.	C^{le} fr. M^{el} Ch. fer.	90 *(56)*	4	17.4 *(17.2)*	Rev. No trail.	43	1934	30 000 *(18 600)*	Local.
2 « C^{le} française de Matériel de Ch. de fer » railcars with two 140-H.P. Saurer diesel engines (Nord).									
Electr.	Oerlikon.	100 *(62)*	12	30 *(29.5)*	Rev. No trail.	62	1935	17 000 *(10 560)*	Local. Interurban.
On trial or under construction.									
Seven 36-seater Michelines with one 220-H.P. Hispano petrol engine (State, Nord).									
Mech.	Hispano.	105 *(65.3)*	12	7 *(6.9)*	Rev.	36	...	...	...
Eighteen 56-seater Michelines with one 220-H.P. Hispano petrol engine (State, Nord, Est).									
Mech.	Hispano.	105 *(65.3)*	16	7.8 *(7.7)*	Rev. Twins.	56	...	...	...
43 Renault railcars with one 265-H.P. diesel engine (All Railways) (*).									
Mech.	Renault.	120 *(75)*	8	28 *(27.6)*	Rev. No trail.	70	...	...	...
6 Renault double railcars with two 265-H.P. Renault diesel railcars (State and P.L.M.) (*).									
Mech.	Renault.	140 *(87)*	12	51 *(50.2)*	Rev. No trail.	116	...	...	...
6 Renault railcars with one 110-H.P. Renault diesel engine (Nord).									
Mech.	Renault.	90 *(56)*	4	9 *(8.9)*	Rev. No trail.	30	...	...	...
36 de Dietrich railcars with two 100-H.P. C.L.M. diesel engines (Various Railways) (*).									
Mech.	Mylius.	100 *(62)*	8	26 *(25.6)*	Rev. No trail.	50 to 70	...	...	...
16 A.D.N. railcars with one 280-H.P. Acénor diesel engine (P.L.M. and P.O.) (*).									
Mech.	Winter-thur.	120 *(75)*	8	32 *(31.5)*	Rev. No trail.	64	...	...	...
41 A.D.N. (so-called Standard) railcars with two 265-H.P. Renault diesel engines (Est, Nord, P.O.-Midi) (*).									
Mech.	Winter-thur.	120 *(75)*	8	38 *(37.4)*	Rev. Trailer.	60	...	...	...

(*) *Note.* — Railcars marked (*) have been described in the text.

Transmission.		Maximum speed on the level km. (*miles*).	Number of wheels	Weight empty, in working order. t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*).	Kind of service.
Type.	Builders.								
4 Bugatti railcars with four 200-H.P. Bugatti petrol engines (3 of which with trailer) (State).									
Hydr.	Bugatti.	150 *(93)*	32	54 *(53.1)*	Rev.	74	...	...	...
23 Bugatti railcars with two 200-H.P. Bugatti petrol engines (Als.-Lorr., State, P.L.M.).									
Hydr.	Bugatti.	130 *(80.8)*	16	20 *(19.7)*	Rev. No trail.	72	...	...	...
8 Franco-Belge triplets with two 410-H.P. Maybach diesel engines (Nord).									
Electr.	Jeumont.	150 *(93)*	24	117 *(115.1)*	Rev.	140	...	...	...
4 Charentaises railcars with two 140-H.P. Saurer diesel engines (State).									
Mech.	Minerva.	120 *(75)*	8	25 *(24.6)*	Rev. No trail.	82	...	...	...
2 Baudet-Donon-Roussel railcars with two 140-H.P. Saurer diesel engines (Nord).									
Mech.	Cotal.	100 *(62)*	4	26 *(25.6)*	Rev. No trail.	65	...	...	...
2 Baudet-Donon-Roussel railcars with one 135-H.P. Berliet diesel engine (Est).									
Mech.	Cotal.	100 *(62)*	4	16 *(15.7)*	Rev. Twins.	71	...	...	...
11 S.O.M.U.A. articulated railcars with one 280-H.P. M.A.N. diesel engine (P.L.M.).									
Mech.	S.O.M.U.A.	85 *(52.8)*	8	29 *(28.5)*	Rev. No trail.	76	...	...	...
3 Decauville railcars with one 300-H.P. Saurer diesel engine (P.L.M.).									
Electr.	Oerlikon.	110 *(68.3)*	8	29 *(28.5)*	Rev. Twins.	71	...	...	...
4 Decauville railcars with two 300-H.P. Saurer diesel engines (P.L.M.).									
Electr.	Oerlikon.	110 *(68.3)*	8	35 *(34.4)*	Rev. Trailer.	71	...	...	...
2 Delaunay-Belleville railcars with one 65-H.P. Delaunay diesel engine (P.L.M.).									
Mech.	Delaunay-Belleville.	90 *(56)*	4	11.7 *(11.5)*	Not rev. No trail.	40	...	...	...
2 Batignolles-Bacalan railcars with two 140-H.P. Saurer diesel engines (Est).									
Mech.	Winterthur.	100 *(62)*	8	29 *(28.5)*	Rev. No trail.	56	...	...	...
4 Société Centrale de Chemins de fer railcars with one 125-H.P. Berliet diesel engine (Est).									
Mech.	...	90 *(56)*	8	13.5 *(13.3)*	Not rev. No trail.	49	...	...	...
4 Lorraine railcars with two 130-H.P. Lorraine diesel engines (Est).									
Mech.	...	100 *(62)*	8	24.5 *(24.1)*	Rev. No trail.	47	...	...	...

Transmission.		Maximum speed on the level km. (*miles*).	Number of wheels	Weight empty, in working order. t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*).	Kind of service.
Type.	Builders.								
2 Berliet railcars and 4 Berliet rail motor vans with two 125-H.P. engines (P.L.M.).									
Electr.	...	100 *(62)*	8	32 *(31.5)*	Rev. Trailer.	63 (rail-cars).	...	...	...
1 Atelier du Nord de la France steam railcar with two 150-H.P. Sentinel engines (Nord).									
Mech.	...	95 *(59)*	8	44 *(43.3)*	Rev. No trail.	65	...	...	...
2 Ateliers du Nord de la France steam railcars with two 200-H.P. Sentinel engines (Est).									
Mech.	...	100 *(62)*	8	38 *(37.4)*	Rev. No trail.	61	...	...	...

Hellenic Republic.

The Railways of the Hellenic Republic now have under construction at the Wiener Lokomotiv Fabrik A. G., Wien (Floridsdorf), 2 railcars with Mannheim Benz engines, with Elin A. G. electric transmission; these 8-wheeled railcars will have 74 seats, will run at a maximum speed of 80 km. (50 miles) an hour and weigh 39 t. (38.4 Engl. tons).

Netherlands.

At the end of 1929 the Netherlands Railways had a stock of 34 railcars, i.e. :

20 with four, and 14 with two pairs of wheels.

26 had petrol engines, and 8 diesel engines, the power of all these engines being about 100 H.P., and they all had mechanical transmission.

The experience obtained by the Netherlands Railways in operating these railcars led them to the conclusion that, from the economical point of view, engines using gas oil were better and that high-speed, high-capacity vehicles were needed.

On the other hand, the recent improvement of the highway system made competition from road transport more severe.

Consequently, early in 1933, the Netherlands Railways passed an order for 40 triple-unit railcars, 35 of which are equipped with two 410-H.P. Maybach diesel engines, and 5 with two 350-H.P. Ganz diesel engines.

28 rakes were put into service at the same time in 1934.

Unhappily, some failures occurred, which much affected the operation.

As a matter of fact, the Maybach engines, which worked faultlessly during the first 20 000 km. (12 400 miles), then began to show abnormal wear in the roller-bearing axle boxes, and after 10 000 more km. (6 200 miles) had been covered, the play in these bearings increased in such a way that breakages occurred at several points.

This failures were first attributed to the fact that the diesel engines developed to high a torque for rotational speeds below the nominal speed : the electric transmissions were altered accordingly.

On the other hand, methodical stationary tests, also showed that the engine crankshaft developed bending vibra-

Fig. 125. — Dutch triplet with two 400-H.P (approx.) diesel engines.

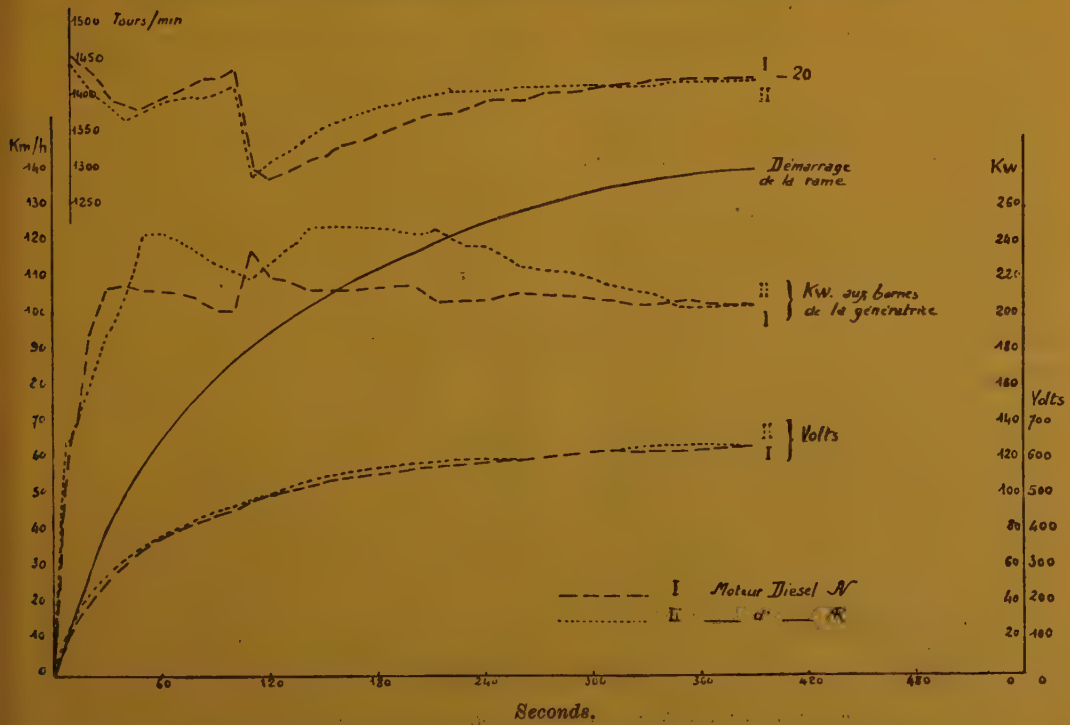


Fig. 126. — Starting curve of Duch triplet (trials on 3rd July, 1934).

Note: Tours min. = r. p. m. — Démarrage de la rame = Starting curve of set. — Kw. aux bornes... = Kw. at the generator terminals. — AV = Front. — AR = Rear.

tions, as opposed to torsional vibrations, at certain critical speeds, which could be ascertained in a precise manner : the builder was thus led to balance the crankshafts by means of counterweights, and it has been shown today that, between 800 and 1 400 r.p.m., there are no more critical speeds.

At present, 8 rakes with Ganz engines and a few with Maybach engines are in service.

*4-bogie triplets with two 410-*H.P. *diesel engines, and electric transmission (fig. 125).* 40 sets, 35 of which with Maybach engines, and 5 with Ganz engines.

Each of these railcars is a set of three bodies connected up with diaphragms, and carried on four bogies; the three units form a single indivisible unit, somewhat like the German « Schnelltriebwagen », but larger.

Each of the intermediate bogies has two separate centres very near each other, on which the two bodies carried on them rest.

The diesel engines and the electrical equipment are carried in the middle body. Owing to the weight of this unit, the two bogies on which it is carried have three pairs of wheels. On each of the two intermediate bogies the two outer pairs of wheels are driven by the traction motors, the middle pair of wheels being a carrying pair.

The two outer bogies of the set are simply carrying bogies.

There is a driving compartment at each end of the set. The number of seats is 48-second class and 112-third class, i. e. 160 altogether.

The weight of the set, in running order but empty, is 97 t. (95.5 Engl. tons) and its maximum speed is 140 km. (80.7 miles) an hour. Each rake is fitted at each end with a Scharfenberg automatic coupling device which automatically couples up the electrical and pneumatic connections between two trains and makes it possible to connect two sets together and have them driven by a single man.

The question of heating received special attention from the Netherlands Railways and the solution adopted was very carefully thought out.

We give (fig. 126) the very favourable starting results obtained during the trials with the 29th set on the 3rd July, 1934.

NETHERLANDS.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*).	Kind of service.
In service.									
20 two-bogie railcars of various designs with two 100-H.P. (approx.) petrol engines.									
Mech.	N.A.G. and Deutsche Werke, Kiel.	75 *(46.6)*	8	32 to 45 *(31.5 to 44.3)*	Rev. Twins. Trailer.	65 to 76	1923 to 1929	252 000 to 623 000 *(156 600 to 387 100)*	Local.
6 Allan railcars with one 100-H.P. Bussing petrol engine.									
Mech.	Deutsche Getriebe.	60 *(37.3)*	4	19.5 *(19.2)*	Rev. Twins. No trail.	40	1929	169 400 *(105 260)*	Local.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*).	Kind of service.
8 railcars of various designs with one 70-H.P. M.A.N. diesel engine.									
Mech.	Deutsche Getriebe.	50 *(31)*	4	18.5 *(18.2)*	Rev. No twins. No trail.	43	1927	249 000 *(154 700)*	Local.
35 three-car sets on 4 bogies, with two 410-H.P. Maybach diesel engines (*).									
Electr.	Heemaf Brown-B.	140 *(87)*	20	98.5 *(97.0)*	Rev. Triplets.	160	1934	...	Ord. expr. Fast expr.
5 three-car sets on 4 bogies with two 350-H.P. Ganz diesel engines.									
Electr.	Smit-Westing-house.	140 *(87)*	20	107 *(105.3)*	Rev. Triplets.	160	1934	...	Ord. expr. Fast expr.

(*) *Note.* — The 3-coach sets marked (*) are described in the text.

Hungary.

The stock of the Royal Hungarian State Railways at present includes 135 railcars (of which 128 with 4 or 6 wheels, and 7 with 8 wheels).

The whole of these railcars cover 12 500 km. (7 770 miles) daily, i. e. about 25 % of the passenger-kilometres (with the exception of international fast express trains), which represent about 50 000 km. (31 080 miles).

They are mostly worked on branch lines, on which they cover approximately 40 % of the passenger-kilometres.

Two 4-wheeled railcars with two 275-H.P. Ganz diesel engines are now on trial.

The Royal State Railways carried out comparative trials in 1929 with railcars of similar types, some fitted with diesel engines, and the others with petrol engines of the same power. These trials proved the superiority of the diesel very clearly, so that on most of the railcars the petrol engines are being replaced by diesels. It has been calculated that the cost of replacing the engines will be covered in a few years by the saving in fuel.

Mechanical transmission with pneumatic control has been used even on the largest railcars.

All railcars can be run in both directions and can haul one or several trailers.

The railcars are heated by the engine exhaust gases; the trailers have special oil-fired boilers.

The present-day tendency can be characterized by the following types :

— 4- or 6-wheeled Ganz railcars for local services (126 in service).

2-bogie Ganz railcars with 2 engines, for fast services (2 on trial).

— 2-bogie Ganz railcars with one engine, for fast services (2 in service).

6-wheeled Ganz railcars with one 130-H.P. engine (fig. 127).

— One Ganz-Jendrassik 6-cylinder diesel engine, 130 H.P. at 1 350 r.p.m., located in the middle of the vehicle.

— Radiators in the roof;

— Mechanical transmission with pneu-

Fig. 127. — Six-wheeled GANZ railcar with one 130-H.P. Ganz diesel engine.

matic control, Ganz system. Constant-mesh gear box fitted under the floor.

— 46 seats. Weight, 21.0 t. (20.7 Engl. tons).

— Maximum speed : 60 km. (37.3 miles) an hour.

— Can haul three trailers.

The gradient climbing capabilities of this vehicle are shown in figure 128.

The operating cost of 22 Ganz railcars with two and three pairs of wheels, during the years 1932 and 1933, are given below (the cost is given in French francs (100 fr. = 22.40 pengoes).

Working costs of 22 4- and 6-wheeled railcars with one 130 H.P. Ganz-Jendrassik engine.

	Total cost (frs.)	Working costs per km.	Working costs *per mile.*	
Train staff	297 701	0.3259	*0.5245*	
Fuel	319 218	0.4372	*0.7036*	
Lubricants	46 730			
Maintenance and current repairs	81 697	0.0895	*0.1440*	after a mileage of 107 600 km. (*66 860 miles*).
Exceptional repairs	40 731	0.3782	*0.6086*	
Total		1.2308 fr. per km.	*1.9807 fr. per mile.*	

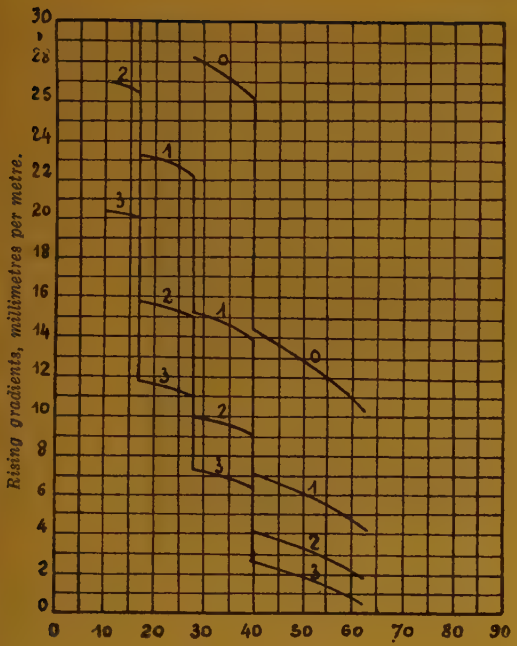
Total annual mileage in commercial service . . . . . 913 939 km. *(567 905 miles).*

Ganz railcar on two bogies, with two 220-H.P. engines (fig. 129).

— Two Ganz-Jendrassik diesel engines developing 220 H.P. at 1 250 r.p.m., one engine on each bogie : the four pairs of wheels are driving wheels.

— Radiators in the roof.

— Mechanical transmission with Ganz pneumatic control.



Curve 0, railcar alone.
Curve 1, railcar with 1 trailer.
Curve 2, railcar with 2 trailers.
Curve 3, railcar with 3 trailers.

Fig 128. — Gradient climbing capability curves of GANZ six-wheeled railcar weighing 24.2 t. (23.8 Engl. tons).

— Constant-mesh gear box, very shallow, fitted under the floor.

— 64 seats. Weight : 42 t. (41.3 Engl. tons).

— Maximum speed : 90 km. (56 miles) an hour, with three trailers, and 60 km. (37.3 miles) with ten trailers.

— Heating by engine cooling water, and by the exhaust gases.

— Knorr brake.

Ganz railcar on two bogies, with one 275-H.P. diesel engine (fig. 130).

— 1 Ganz engine, 275 H.P. at 1 200 r.p.m., 6 cylinders.

— Radiator under the body, carried on the driving bogie.

Fig. 129. — Two-bogie railcar with two 220-H.P. Ganz engines.

Fig. 130. — GANZ railcar on two bogies, with one 275-H.P. Ganz diesel engine.

— Mechanical transmission with Ganz pneumatic control.

— Constant-mesh gear box with 5 speeds.

— 75 seats. Weight : 30 t. (29.5 Engl. tons).

— Maximum speed : 120 km. (75 miles) an hour.

— Heating by engine cooling water.

ROYAL HUNGARIAN STATE RAILWAYS.

Transmission.		Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run km. (*miles*). per vehicle, (1st Jan. 1934).	Kind of service.
Type.	Builders.								
In service.									
51 four-wheeled railcars of various designs with petrol engine.									
Mech.	Various.	55 to 75 *(34.2 to 46.6)*	4	7 to 21 *(6.9 to 20.7)*	Rev. Trailer.	29 to 50	Before 1930	22 000 to 250 000 *(13 670 to 155 350)*	Local.
3 eight-wheeled M.A.V. railcars with two 100-H.P. petrol engines.									
Mech.	National Automobil Gesellschaft.	60 *(37.3)*	8	35 *(34.4)*	Rev. Trailer.	73	Before 1930	220 000 to 300 000 *(136 700 to 186 000)*	Local.

Transmission. Type.	Builders.	Maximum speed on the level km. (*miles*).	Number of wheels	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (1st Jan. 1934).	Kind of service.
	2 eight-wheeled railcars with one diesel engine { *1 with Ganz engine. 1 with Maybach engine.*								
1 mech. 1 hydr.	Various.	60 *(37.3)*	8	30 and 40 *(29.5 and 39.4)*	Rev. Trailer.	80	1926	70 000 and 160 000 *(43 500 and 100 000)*	Local.
	33 four-wheeled railcars with one 130-H.P. Ganz diesel engine.								
Mechanical transmission with pneumatic control, Ganz system.	Ganz.	55 to 75 *(34.2 to 46.6)*	4	20 *(19.7)*	Rev. Trailer.	46	1930 1932	50 000 *(31 000)*	Local.
	42 six-wheeled Ganz railcars with one 130-H.P. Ganz diesel engine.								
	Ganz.	55 to 60 *(34.2 to 37.3)*	6	21 *(20.7)*	Rev. Trailer.	46	1932 1934	60 000 *(37 300)*	Local.
	2 four-wheeled Ganz railcars with one 95-H.P. Ganz diesel engine.								
	Ganz.	90 *(56)*	4	9.4 *(9.2)*	Not rev. No trail.	36	1935	...	Express.
	2 eight-wheeled Ganz railcars with one 275-H.P. Ganz diesel engine (*).								
	Ganz.	120 *(75)*	8	32 *(31.5)*	Rev. No trail.	72	1934	...	Express.
	On trial.								
	2 eight-wheeled Ganz railcars with two 220-H.P. Ganz diesel engines (*).								
	Ganz.	90 *(56)*	8	54 *(53.1)*	Rev. Trailer.	63	...	...	Express.

(*) *Note.* — Railcars marked (*) have been described in the text.

Italy.

The Italian Railways had in service, on the 1st January 1935, 97 railcars, i. e. :

83 with petrol engine and mechanical transmission;

9 with diesel engine and mechanical transmission;

5 with diesel engine and electric transmission.

They had on trial or under construction 82 railcars, of which :

63 with petrol engine and mechanical transmission;

13 with diesel engine and mechanical transmission;

3 with diesel engine and hydraulic transmission;

3 with steam engine.

The Italian Railways were of the opinion that the most difficult problem to be solved in the matter of railcars is not the technical problem but the question of operation. They therefore ordered railcars with petrol engines, which had proved their reliability, and very simple mechanical transmission.

They also considered that passengers would be attracted above all by high overal speeds. Their vehicles have been particularly well designed in this connection, and the builders have tried to

get rapid acceleration by all possible means : Fiat by means of the free wheel which, apart from the facility it gives in running down gradients with the engine declutched and idling, enables the gear to be changed without declutching, which prevents loss of time when changing gear : Breda by means of the preselective gear box on the Wilson system.

The Italian railcars are also characterised by the attention paid to the comfort of the passengers and by their handsome modern decoration.

*Fiat railcar on two bogies, with one 120-*H.P. *petrol engine* (63 in service).

— 1 Fiat petrol engine, 120-H.P. at 2 000 r.p.m. (6 cylinders).

— Radiators at each end of the vehicle.

— Fiat mechanical transmission with pneumatic control.

— Bogie shown in figure 58.

— 48 or 64 seats. Weight : 13 and 15 t. (12.8 and 14.8 Engl. tons).

— Maximum speed : 110 km. (68.3 miles) an hour.

— Pneumatic and hand-operated drum brakes.

*Fiat railcar on two bogies, with two 120-*H.P. *Fiat petrol engines* (9 in service) (fig. 131).

— Two Fiat petrol engines, 120-H.P. at 2 000 r.p.m., 6 cylinders.

Fig. 131. — FIAT 2-bogie railcar (the LITTORINA), with two 120-H.P. Fiat petrol engines.

— Radiators at each end of the vehicle.

— Fiat mechanical transmission with pneumatic control.

— 80 seats. Weight, 21.5 t. (21.2 Engl. tons).

— Maximum speed : 140 km. (87 miles) an hour.

— Pneumatic and hand-operated drum brakes.

— Heating by the exhaust gases.

*Breda railcars on two-bogies, with one 120-*H.P. *petrol engine* (three vehicles in service).

— Isotta Fraschini petrol engine, 120 H.P. at 2 500 r.p.m., 8 cylinders.

Fig. 132. — Two-bogie BREDA railcar with two 130-H.P. diesel engines.

Fig. 133. — EMMINA 4-wheeled railcar with one 100-H.P. diesel engine, Societa Italiana per le Strade ferrate del Mediterraneo.

— Radiators at each end.
— Mechanical transmission.
— Wilson 5-speed gear box.
— 72 seats. Weight, 12.5 t. (12.3 Engl. tons).
— Maximum speed : 120 km. (75 miles) per hour.
— Hydraulic drum brakes.

Breda railcars on 2 bogies, with two 130-H.P. diesel engines (9 on trial and under construction) (fig. 132).

— Two A.E.C. Breda diesel engines, 130 H.P. at 2 000 r.p.m. (6 cylinders).
— Radiators at each end.
— Breda mechanical transmission.
— Wilson gear box, 5 speeds.
— 56 seats. Weight, 22 t. (21.7 Engl. tons).
— Maximum speed : 140 km. (87 miles) per hour.

The « *Societa Italiana per le Strade ferrate del Mediterraneo* » have 35 railcars in service or under construction, 25 of which are four-wheeled vehicles with mechanical transmission, and 10, 8-wheeled with electric transmission.

*4-wheeled Emmina railcars with one 100-*H.P. *diesel engine* (35 in service or under construction) (fig. 133).

— 1 Saurer diesel engine, 100 H.P. et 1 800 r.p.m.

— Carminati & Toselli mechanical transmission.

— 1 driving compartment.

— 35 seats. Weight, 6.6 t. (6.5 Engl. tons).

— Maximum speed : 70 km. (43.5 miles) per hour.

*8-wheeled Piaggio railcars with two 135-*H.P. *diesel engines.*

— 2 Saurer diesel engines, 127 H.P. at 1 600 r.p.m.

— Brown-Boveri electric transmission.

— 2 driving compartments.

— Brill bogie with bolster beam.

— 58 seats. Weight, 17 t. (16.7 Engl. tons).

— Maximum speed : 75 km. (46.6 miles) per hour.

Piedmont.

The General Piedmontese Tramways Company has in service 12 accumulator-driven railcars equipped with 160-cell Tudor batteries, 6 Socièta Nazionale de Saviglione railcars, and 6 Brown-Boveri railcars; they are used on local services and are fitted with the Westinghouse compressed-air brake.

ITALY.

Transmission.		Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (1st. Jan. 1935).	Kind of service.
Type.	Builders.								
In service.									
3 Cemsa railcars with one 100 or 160-H.P. petrol engine.									
Mech.	C.E.M.S.A.	50 *(31)*	8	18 to 25 *(17.7 to 24.6)*	Rev. Twins. Trailer.	45 to 70	1927 1928 1929	50 000 to 100 000 *(31 000 to 62 000)*	Local.
4 Fiat railcars with one 180-H.P. Fiat diesel engine.									
Electr.	Brown-Boveri.	55 *(34.2)*	8	44 *(43.3)*	Rev. Twins. Trailer.	30 to 38	1931	50 000 to 100 000 *(31 000 to 62 000)*	Local.
1 F.S. railcar with one 150-H.P. M.A.N. diesel engine.									
Electr.	F.S.	60 *(37.3)*	8	34 *(33.5)*	Rev. Twins. Trailer.	45	1931	46 000 *(28 580)*	Local.
2 Fiat railcars with one 65-H.P. Fiat petrol engine.									
Mech.	Fiat.	58 *(36)*	4	7 *(6.9)*	Not rev. Trailer.	25	1932	80 000 *(50 300)*	Local.

Transmission.		Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (1st. Jan. 1935).	Kind of service.
Type.	Builders.								
		15 Fiat railcars with one 120-H.P. Fiat petrol engine (*).							
Mech.	Fiat.	110 *(68.3)*	8	14 *(13.8)*	Rev. No trail.	48	1933	55 000 *(34 175)*	Express.
		48 Fiat railcars with one 120-H.P. petrol engine (*).							
Mech.	Fiat.	100 *(62)*	8	17 *(16.7)*	Rev. No trail.	64	1934	48 000 *(29 825)*	Express.
		9 Fiat railcars with two 120-H.P. Fiat petrol engines (*).							
Mech.	Fiat.	130 *(80.8)*	8	22 *(21.65)*	Rev. No trail.	80	1934	50 000 *(31 000)*	Express.
		9 Fiat railcars with two 75-H.P. Fiat diesel engines.							
Mech.	Fiat.	110 *(68.3)*	8	21 *(20.7)*	Rev. No trail.	56	1934	50 000 *(31 000)*	Express.
		3 Breda railcars with one 120-H.P. Isotta Fraschini petrol engine (*).							
Mech.	Isotta Fraschini.	110 *(68.3)*	8	19 *(18.7)*	Rev. No trail.	72	1933	27 000 *(16 780)*	Express.
		3 Fiat rail motor vans with one 120-H.P. Fiat petrol engine.							
Mech.	Fiat.	90 *(56)*	8	15 *(14.8)*	Rev. No trail.	...	1934	8 000 *(5 000)*	Express.
		On trial or under construction.							
		50 Fiat railcars with two 75-H.P. Fiat petrol engines.							
Mech.	Fiat.	110 *(68.3)*	8	16.5 *(16.2)*	Rev. No trail.	56	...	...	...
		10 Breda railcars with two 100-H.P. Breda petrol engines.							
Mech.	Breda.	140 *(87)*	8	20 *(19.7)*	Not rev.	56	...	...	...
		3 Breda rail motor vans with one 100-H.P. Breda petrol engine.							
Mech.	Breda.	80 *(50)*	8	16 *(15.7)*	Rev. No trail.	...	...	...	...
		9 Breda railcars with two 130-H.P. Breda diesel engines (*).							
Mech.	Breda.	140 *(87)*	8	22 *(21.65)*	Rev. No trail.	56	...	...	...
		1 Breda railcar with two 80-H.P. Breda diesel engines.							
Mech.	Breda.	...	8	20 *(19.7)*	Rev.	56	...	...	...
		3 Officine Ferr. Meridionale railcars with two 110-H.P. Alfa Romeo diesel engines.							
Mech.	O.F.M.	110 *(68.3)*	8	23 *(22.6)*	Rev. No trail.	68	...	...	...

(*) *Note.* — Railcars marked (*) have been described in the text.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*).	Kind of service.
3 Officine Mecc. Milano railcars with two 125-H.P. O.M. diesel engines.									
Hydr.	O.M. Trylok.	120 *(75)*	8	24 *(23.6)*	Rev. No trail.	72	...	...	...
3 Officine Mecc. Milano railcars with two 110-H.P. steam engines.									
...	O.M.	120 *(75)*	8	23.5 *(23.1)*	Rev. No trail.	72	...	...	...

Norway.

The Norwegian Railways have in service 53 railcars of various designs, with mechanical transmission. They are used for local services.

NORWAY.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order. t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (1st. Jan. 1935).	Kind of service.
In service.									
21 four-wheeled railcars of various designs, with a petrol engine developing about 100-H.P.									
Mech.	Various.	55 *(34.2)*	4	10 to 16 *(9.8 to 15.7)*	Not rev. Trailer.	30 to 50	1924 to 1930	300 000 to 550 000 *(186 400 to 341 750)*	Local.
11 four-wheeled N.S.B. railcars with two 120 and 80-H.P. Buda petrol engines.									
Mech.	N.S.B.	65 *(40.4)*	4	14 *(13.8)*	Not rev. Trailer.	52	1929 1930	310 000 *(192 600)*	Local.
8 four-wheeled A/S Strommens Verksted railcars with two 250-H.P. petrol engines.									
Mech.	A/S Strommens Verksted.	70 *(43.5)*	4	18 *(17.7)*	Rev. Trailer.	50	1932	130 000 *(80 780)*	Local.
2 Deutsche Werke 2-bogie railcars with one 160-H.P. Mercedes petrol engine.									
Mech.	Deutsche Werke.	60 *(37.3)*	8	25 *(24.6)*	Rev. Trailer.	56	1923	290 000 *(180 200)*	Local.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (1st. Jan. 1935).	Kind of service.
3 A/S Skabo two-bogie railcars with two T.A.G. petrol engines developing 300-H.P.									
Mech.	T.A.G.	70 *(43.5)*	8	34.5 *(33.9)*	Rev. Trailer.	66	1932	140 000 *(87 000)*	Local.
4 A/S Strommens Verksted two-bogie railcars with two Buda petrol engines developing 240-H.P.									
Mech.	N.S.B.	65 *(40.4)*	8	19 *(18.7)*	Rev. Trailer.	56	1932	80 000 *(50 000)*	Local.
3 four-wheeled A/S Strommens Verksted railcars with 2 Buda petrol engines, developing 240-H.P.									
Mech.	N.S.B.	70 *(43.5)*	4	17.4 *(17.1)*	Rev. Trailer.	50	...	50 000 *(31 000)*	Local.
1 four-wheeled A/S Strommens Verksted railcar with 2 Mercedes-Benz diesel engines, developing 300-H.P.									
Mech.	N.S.B.	90 *(56)*	4	18 *(17.7)*	Rev. Trailer.	50	...	25 000 *(15 500)*	Local.

Poland.

The Polish Railways have eleven railcars in service; ten of these are steam-driven and one has a petrol engine.

3 trial railcars have been built in Poland for branch line service, and if the tests give satisfactory results, railcar services are likely to be extended.

POLAND.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (1st Jan. 1934).	Kind of service.
In service.									
9 Clayton steam railcars, 110-H.P.									
...	Clayton.	70 *(43.5)*	8	42 *(41.3)*	Rev. Trailer.	70	1931-1933	28 000 *(17 400)*	Local.
1 Sentinel steam railcar, 120-H.P.									
...	Sentinel.	60 *(37.3)*	8	31 *(30.5)*	Rev. Trailer.	63	1930	136 000 *(84 510)*	Local.
1 Austro-Daimler railcar with two 80-H.P. Daimler petrol engines.									
Hydr.	Voith.	100 *(62)*	8	19 *(18.7)*	Rev. Trailer.	60	1933	15 000 *(9 320)*	Express.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*).	Kind of service.
On trial.									
1 railcar with two 100-H.P. Saurer diesel engines.									
Mech.	Mylius.	85 *(52.8)*	8	27.5 *(27.1)*	Rev. Trailer.	72	...	...	...
1 railcar with two 200-H.P. Eberman diesel engines.									
Mech.	...	85 *(52.8)*	8	40 *(39.4)*	Rev. Trailer.	68	...	...	...
1 railcar with one 100-H.P. Saurer diesel engine.									
Mech.	Mylius.	85 *(52.8)*	4	14 *(13.8)*	Rev. Trailer.	50	...	...	...

Portugal.

The Mozambique Colony has just put into service 2 Michelin railcars with one 85-H.P. Panhard petrol engine; these vehicles have 12 wheels fitted with pneumatic tyres. They provide 22 seats and can haul a 4-wheeled 12-seater trailer on pneumatic tyres.

The railcar and its trailer are equipped with the Lockheed hydraulic brake.

PORTUGAL.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels	Weight empty, in working order. t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (1st. Jan. 1935).	Kind of service.
In service in the Mozambique Colony.									
2 Michelin railcars with one 85-H.P. Panhard petrol engine (*).									
Mech.	Panhard.	85 *(52.8)*	12	6.5 *(6.4)*	Not rev. 1 trailer.	22 12 trail	...	15 200 *(9 445)*	Express.
Under construction for the Mozambique Colony.									
2 « South African Railways and Harbours » railcars with two 70-H.P. Hudson petrol engines.									
Mech.	Hudson.	64 *(40)*	6	13.6 *(13.4)*	Not rev. No trail.	13	...	...	Local.

(*) *Note.* — The railcar marked (*) is described in the text.

Sweden.

The Royal Swedish State Railways had on the 1st January 1935, 15 railcars in service and 3 under construction, subdivided as follows :

In service :

— 8 petrol or diesel railcars of old design.

— 2 railcars with two 100-H.P. petrol engines; 8 wheels. Weight, 34 t. (33.5 Engl. tons). Maximum speed : 74 km. (46 miles) per hour.

— 7 railbuses with one 100-H.P. petrol engine and mechanical transmission; 4 wheels. Weight, 6.2 t. (6.1 Engl. tons). Maximum speed : 80 km. (50 miles) an hour. 24 seats (fig. 134).

Fig. 134. — Railbus with one 100-H.P. petrol engine.

Under construction :

— 3 railbuses as described above.

The Bergslagen Railways have had a four-wheeled Nohab railcar in service since 1933. This vehicle has a 90-H.P. Maybach diesel engine (6 cylinders) with mechanical transmission. The engine is elastically suspended at three points and well isolated from the body so as to prevent noise and vibration.

This vehicle has 40 seats and weighs 7.4 t. (7.3 Engl. tons) empty. It can run at 75 km. (46.6 miles) an hour on the level. It can only run in one direction and cannot haul a trailer.

The Halmstad Nässjo Railway has D.E.V.A. diesel-electric railcars dating from 1914-24. Several railcars of various designs (Austro-Daimler, A.S.E.A., etc.) and some railbuses are under construction.

The Vastergötland Railway has a stock of railcars which consists of 5 petrol-engined vehicles which can all run in either direction and can haul trailers. All these vehicles have mechanical transmission with pneumatic control.

The other Swedish private Companies have 17 railcars in service and 8 on order, subdivided as follows :

17 in service :

9 with diesel engine, and 8 with petrol engine;

12 with mechanical transmission, 5 with electric transmission.

8 on order :

4 with diesel engine, and 4 with petrol engine;

4 with electric transmission, 1 with hydraulic transmission, 3 with mechanical transmission.

Switzerland.

The Federal Railways have two Diesel-electric railcars in service, one of which has a 250-H.P. engine and the other a 420-H.P. engine. They weigh about 60 t. (59 Engl. tons).

They have under construction, at the Winterthur Locomotive and Engine Works, two diesel railcars described as follows :

1 Sulzer diesel engine, 300 H.P. at 1 200 r.p.m. (6 cylinders).

Winterthur mechanical transmission controlled by oil under pressure.

Two driving compartments.

70 seats. Weight : 29.5 t. (29 Engl. tons).

Maximum speed : 125 km. (77.7 miles) an hour.

Compressed-air brakes.

Heating by hot air.

Czechoslovakia.

The Czechoslovak Railways have 390 railcars in service at the present time, and 58 are on trial or under construction. These can be classified into two distinct classes :

1. Railbuses, which are light vehicles, of no great speed, with low-power engines, intended for branch lines.

2. Faster and heavier railcars fitted with high-power engines for main-line service.

1. *Railbuses.*

The first types of such vehicles, put into service in 1927, do not haul trailers and cannot be reversed. The Czechoslovak Railways soon discovered the drawbacks of this type of vehicle, and in 1928 they designed new railbuses of higher power, which could haul one or two trailers. These vehicles and their trailers were fitted with a central buffer which had the drawback of making it impossible to haul carriages and wagons of the « railway » type. Finally, in 1930, they put into service railbuses fitted with the usual type of buffing and draw gear.

The railbuses with petrol engines use Czechoslovak national fuel or dynalcohol which is made up of : 70 % petrol, 26 % dehydrated alcohol, and 4 % benzol.

The rail omnibuses are heated by the exhaust gases, while the trailers are heated by a special coke stove.

Four-wheeled Tatra railbus (109 vehicles in service, 12 under construction).

— 1 Tatra petrol engine, 115 H.P. at 1 200 r.p.m., 6 cylinders, carried in the middle of the vehicle.

— Radiators under the floor.

— Mechanical transmission.

— The vehicle can run in either direction, the driver being in a raised central compartment.

— 42 seats. Weight : 12.6 t. (12.4 Engl. tons).

— Maximum speed : 60 km. (37.3 miles) an hour.

Four-wheeled C.K.D. railbus with one 150-H.P. diesel engine (fig. 135) (19 in service, 6 under construction).

— One C. K. D. horizontal diesel engine, 150 H.P. at 1 100 r.p.m., located under the vehicle.

— C.K.D. electric transmission.

— 2 driving axles.

Fig. 135. — 4-wheeled C.K.D. railcar with one 150-H.P. C.K.D. horizontal diesel engine.

— Can be driven in both directions — 2 driving compartments.

— 58 seats. Weight, 20 t. (19.7 Engl. tons).

— Maximum speed : 65 km. (40.4 miles) an hour.

Four-wheeled Skoda railbus with one 120-H.P. diesel engine (29 vehicles in service).

— One Skoda diesel engine, 120 H.P. at 1 600 r.p.m., 8 cylinders carried in the middle of the vehicle under the floor, on special sub-frame.

— Mechanical transmission, Skoda design. 2 pairs of driving wheels.

— Can run in either direction : driving compartment at each end.

— 55 seats. Weight : 19.0 t. (18.7 Engl. tons).

— Maximum speed : 60 km. (37.3 miles) an hour.

Trailers :

Two types :

1. 36 seats. Weight : 8.2 t. (8.1 Engl. tons). Luggage compartment measuring 6.72 m² (72 sq. feet).

— 2. 46 seats. Weight : 8 t. (7.9 Engl. tons). No luggage compartment.

2. *Railcars.*

The railcars for main-line services have bogies and can all run in either direction. As a rule they are equipped with diesel engines and electric transmission.

The brakes are of the Knorr type improved by Skoda. Electro-magnetic brakes are not used.

Ceskomoravska - Kolben - Danek eight-wheeled railcar with one 350-H.P. diesel H.P. (10 in service).

— C.K.D. Hesselman diesel engine 350 H.P. at 900 r.p.m., 6 cylinders.

— Radiators on the roof.

— C. K. D. electric transmission.

— The leading bogie carries the diesel engine and the generator, and the trailing bogie, the two traction motors (fig. 71).

— Can haul one or two carriages.

— Maximum speed, railcar by itself, 100 km. (62 miles) an hour.

— 64 seats. Weight : 47 t. (46.3 Engl. tons).

Fig. 136. — 2-bogie Skoda railcar with one 400-h.p. Skoda diesel engine.

— Fuel oil consumption : 7 to 8 gr. per tkm. (0.398 to 0.455 oz. per Engl. ton-mile).

*Brno-Kralovopolska 4-wheeled railcar with two 120-*h.p. *or 160-*h.p. *diesel engines* (6 in service, 2 under construction or on trial).

— Two Brno-Kralovopolska diesel engines, 160 or 120-h.p. at 1 300 r.p.m.

— 8 cylinders arranged in V.

— Radiators on the roof.

— Brown - Boveri electric transmission.

— Two identical bogies each carrying one Diesel engine, one generator and one traction motor (fig. 73).

— 80 seats. Weight : 42 t. (41.3 Engl. tons).

— Maximum speed : 100 km. (62 miles) an hour.

— Can haul one or two trailers.

*4-wheeled Skoda railcar with one 400-*h.p. *diesel engine* (6 in service, 3 on trial or under construction) (fig. 136).

— One Skoda diesel engine, 400 h.p. at 1 000 r.p.m. (8 cylinders).

— Skoda electric transmission.

— The leading bogie carries the diesel engine; the trailing bogie is driving.

— 56 seats. Weight, 49 t. (48.2 Engl. tons).

— Maximum speed : 100 km. (62 miles) an hour.

* * *

The Czechoslovak Railways, basing their calculations on the results obtained up to the present, estimate as follows the working costs of steam traction and diesel-electric traction, in crowns.

	Steam traction.		Diesel-electric traction.	
	Per train-km.	*Per train-mile.*	Per train-km.	*Per train-mile.*
Amortisation	3.21	*(5.16)*	1.83	*(2.94)*
Maintenance	2.19	*(3.52)*	0.90	*(1.45)*
Staff	2.20	*(3.54)*	0.51	*(0.82)*
Fuel	1.52	*(2.45)*	0.77	*(1.24)*
Lubricant	0.16	*(0.26)*	0.35	*(0.56)*
Total	9.28	*(14.93)*	4.36	*(7.01)*
i. e. per 100 seats	3.10	*(4.99)*	3.11	*(5.00)*

These figures were based on 300 seats per steam train and 140 seats in the case of a railcar with a trailer.

CZECHOSLOVAKIA.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (1st. Jan. 1935).	Kind of service.
In service.									
89 petrol railcars of various designs, with mechanical transmission.									
Mech.	Various.	45 to 80 *(28 to 50)*	14 eight-wh. 75 four-wh.	7 to 34 *(6.9 to 33.5)*	12 not rev. Trailer. 77 rev. Trailer.	30 to 86	Before 1930	141 000 to 420 000 *(87 600 to 261 000)*	Local.
18 petrol railcars of various designs with electric transmission.									
Electr.	Various.	45 to 60 *(28 to 37.3)*	3 eight-wh. 15 four-wh.	13 to 42 *(12.8 to 41.3)*	Rev. Trailer.	34 to 82	1929 1930 1931	114 000 to 180 000 *(70 800 to 111 850)*	Local.
2 Severoceska-Vozovka railcars with one 150-H.P. M.A.N. diesel engine.									
Electr.	Brown-Boveri.	70 *(43.5)*	4	28.6 *(28.1)*	Rev. Trailer.	44	1931	86 800 *(53 940)*	Local.
29 Skoda railcars with one 120-H.P. diesel engine.									
Electr.	Skoda.	80 *(50)*	4	19 *(18.7)*	Rev. Trailer.	55	1932 1934	40 000 *(25 000)*	Local.
52 Skoda railcars with one 120-H.P. Skoda petrol engine (*).									
Mech.	Skoda.	65 *(40.4)*	4	13 *(12.8)*	Rev. Trailer.	38	1932 1933 1934	70 000 *(43 500)*	Local.

(*) *Note.* — Railcars marked (*) have been described in the text.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order. t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (1st. Jan. 1935).	Kind of service.
		48 Moravsko-Slezskà railcars with one 120-H.P. Tatra petrol engine.							
Electr.	Gebus and C.K.D.	50-60 *(31-37.3)*	4	18.7 *(18.4)*	Rev. Trailer.	48	1930 1932	129 000 *(80 160)*	Local.
		109 Tatra railcars with one 115-H.P. Tatra petrol engine (*).							
Mech.	Tatra.	50-60 *(31-37.3)*	4	12.5 *(12.3)*	Rev. Trailer.	42	1931 1932	75 000 *(46 600)*	Local.
		19 C.K.D. railcars with one 150-H.P. C.K.D. diesel engine.							
Electr.	C.K.D.	75 *(46.6)*	4	19 *(18.7)*	Rev. Trailer.	52	1934	13 000 *(8 080)*	Local.
		1 Skoda railcar with one 300-H.P. Skoda diesel engine.							
Electr.	Skoda.	80 *(50)*	8	50 *(49.2)*	Rev. Trailer.	53	1932	44 369 *(27 570)*	Local.
		5 Skoda railcars with one 400-H.P. Skoda diesel engine.							
Electr.	Skoda.	100 *(62)*	8	39 *(38.4)*	Rev. Trailer.	56	1934	10 000 *(6 200)*	Express.
		2 Tatra railcars with two 100-H.P. Tatra petrol engines.							
Mech.	Tatra.	80 *(50)*	8	39 *(38.4)*	Rev. Trailer.	68	1932	114 156 *(70 935)*	Express.
		2 Ceskomoravska-Kolben-Danek railcars with one 300-H.P. C.K.D. engine (*).							
Electr.	Westing-house C.K.D.	90 *(56)*	8	53 *(52.2)*	Rev. Trailer.	54	1933	35 246 *(21 900)*	Express.
		8 C.K.D. railcars with one 350-H.P. C.K.D. diesel engine.							
Electr.	C.K.D.	100 *(62)*	8	47 *(46.3)*	Rev. Trailer.	64	1934	49 000 *(30 450)*	Express.
		2 Brno-Kralovopolska railcars : One with 2 Brno-Kralovopolska petrol engines developing 120-H.P. One with 2 Brno-Kralovopolska diesel engines developing 120-H.P.							
Electr.	Brown-Boveri.	54 *(33.5)*	8	53 *(52.2)*	Rev. Trailer.	54	1933	35 246 *(21 900)*	Express.
		4 Brno-Kralovopolska-Vozovka railcars with two 160-H.P. B.K.V. engines (*).							
Electr.	Brown-Boveri.	100 *(62)*	8	43 *(42.3)*	Rev. Trailer.	82	1933 1934	17 000 *(10 560)*	Express.
		On trial or under construction.							
		8 Skoda railcars with one 120-H.P. Skoda petrol engine (*).							
Mech.	Skoda.	65 *(40.4)*	4	13.6 *(13.4)*	Rev. Trailer.	42	...	...	Local.

(*) *Note.* — Railcars marked (*) have been described in the text.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*).	Kind of service.
		12 Tatra railcars with one 115-H.P. Tatra petrol engine (*).							
Mech.	Tatra.	60 *(37.3)*	4	12.7 *(12.5)*	Rev. Trailer.	42	...	...	Local.
		10 Tatra railcars with one 115-H.P. M.A.N. diesel engine.							
Mech.	Tatra.	60 *(37.3)*	4	13 *(12.8)*	Rev. Trailer.	42	...	...	Local.
		15 Moravsko-Slezskà railcars with one 120-H.P. M.A.N. diesel engine.							
Electr.	C.K.D.	60 *(37.3)*	4	18 *(17.7)*	Rev. Trailer.	48 58	...	...	Local.
		1 Moravsko-Slezskà railcar with one 120-H.P. producer-gas engine.							
Electr.	C.K.D.	60 *(37.3)*	4	18 *(17.7)*	Rev. Trailer.	58	...	...	Local.
		3 Skoda railcars with one 400-H.P. Skoda diesel engine.							
Electr.	Skoda.	110 *(68.3)*	8	50 *(49.2)*	Rev. Trailer.	56	...	...	Express.
		7 C.K.D. railcars with one 150-H.P. C.K.D. diesel engine.							
Electr. Mech.	C.K.D.	65 *(40.4)*	4	20 *(19.7)*	Rev. Trailer.	58	...	...	Local.
		2 Kralovopolska-Vozovka railcars with two 200-H.P. Kralovopolska diesel engines.							
Electr.	Brown-Boveri.	100 *(62)*	8	44 *(43.3)*	Rev. Trailer.	77	...	...	Express.

(*) *Note.* — Railcars marked (*) have been described in the text.

Turkey.

The Turkish Railways put into service, in February 1933, three Esslingen steam railcars designed as follows :

— Boiler : water tubes, 25 kgr./cm² (355 lb. per sq. inch).

— Driving gear carried on a truck.

— A single driving axle.

— Poppet valve gear with Walschaerts link motion.

— Semi-automatic firing, so that the vehicle can be driven by a single man.

— The leading end of the body is carried on the back of the driving unit, and its other end on a carrying bogie.

— The vehicle cannot be reversed.

— It can haul one or several trailers.

— 56 seats. Weight : 53 t. (52.2 Engl. tons).

— Maximum speed : 100 km. (62 miles) an hour.

— Kunze-Knorr compressed air brake.

TURKEY.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*). (1st. Jan. 1935).	Kind of service.
In service.									
3 Esslingen railcars with one 450-H.P. steam engine (*).									
...	...	100 *(62)*	8	53 *(52.2)*	Not rev. Can be coupl. up. Trailer.	56	1933	40 000 *(25 000)*	Fast local.
Under construction.									
6 Skoda railcars with one 75-H.P. petrol engine.									
Mech.	Skoda.	60 *(37.3)*	4	10.4 *(10.2)*	Rev. No trail.	32	...	...	Local.

(*) *Note.* — Railcars marked (*) have been described in the text.

Jugoslavia.

The Jugoslav State Railways have two 4-wheeled Ganz railcars in service.

They also have 6 railcars on order, 3 of light weight and 3 of heavier design.

4- wheeled Ganz railcars (2 in service).

— One Ganz petrol engine, 90 H.P at 1 150 r.p.m. located in the middle of the body.

— Mechanical transmission with pneumatic control.

— 46 seats. Weight 17.5 t. (17.2 Engl. tons).

— Maximum speed : 55 km. (34.2 miles) per hour.

12-wheeled Odense railcars (3 on order).

— One 225-H.P. Burmeister & Wain diesel engine.

— Thrige electric transmission.

— 3 bogies, 2 of which carrying; the middle bogie supports the engine, generator and other gear. The wheelbase of the latter bogie is 5.60 m. (18 ft. 4 1/2 in.).

JUGOSLAVIA.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. (*miles*).	Number of wheels.	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*).	Kind of service.
In service.									
Mech.	Ganz.	55 *(34.2)*	4	17.5 *(17.2)*	Rev. Trailer.	46	1928	...	Local.

Transmission.		Maximum speed on the level km. (*miles*).	Number of wheels	Weight empty, in working order, t. (*Engl. tons*).	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. (*miles*).	Kind of service.
Type.	Builders.								
Under construction.									
2 Odense railcars with one 75-H.P. Hesselman diesel engine.									
Mech.	Z. F.	70 *(43.5)*	4	13.5 *(13.3)*	Rev.	50	...	...	Fast local.
1 Odense railcar with one 75-H.P. Hesselman diesel engine.									
Hydr.	Voith.	70 *(43.5)*	4	14 *(13.8)*	Rev.	50	...	...	Fast local.
3 Odense railcars with one 225-H.P. Burmeister & Wain diesel engine.									
Electr.	Thrige.	70 *(43.5)*	12	53.5 *(52.6)*	Rev. Trailer.	75	...	...	Fast local.

[621.43]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

INQUIRY INTO QUESTIONS OF IMMEDIATE INTEREST.

(Decision taken by the Permanent Commission at its Meeting held on July 29th, 1933.)

QUESTION I.

Rail motor cars from the point of view of their construction.

SPECIAL REPORT

by L. DUMAS,

Ingénieur en chef adjoint du Matériel et de la Traction, French Nord Railway,

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I. — General.
II. — Steam railcars.
III. — Petrol railcars.
IV. — Railcar diesel engines.
V. — Railcar transmissions.
VI. — Railcar bogies.
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VIII. — Railcar underframe and body.
IX. — Comfort in railcars.
X. — High-capacity railcars — Triplet sets.
XI. — Comparative tests of railcars.
XII. — Cost price of railcars.
Summaries.

* * *

I. — General.

The majority of railway companies are ordering rail motor cars fitted with heat engines, as is shown by the following table of cars ordered and under construction in Continental Europe on the 1st January 1935 :

Battery railcars	0
Steam railcars	16
Petrol railcars	144
Diesel railcars	540

Several *battery railcars* in use in Ireland, Italy, and the United States give satisfactory results.

The use of this type of railcar does not seem likely to increase, no doubt because of its limited radius of action.

Steam railcars are very widely used in certain countries, such as England, Rumania, Poland, etc., but up to the present cannot be single-man operated when coal fired. Non-condensing *steam railcars*, moreover, require considerable supplies of water.

For these reasons, much attention has been given to perfecting automatic firing in conjunction with oil fuel and condensing engines. Nine automatic steam cars are being built in Germany, and several in France and Italy.

Petrol railcars are still much in evidence and are being built : in Italy (50 *Fiat*, 13 *Breda)*, France (27 *Bugatti*, 25 *Michelines*), Czechoslovakia (12 *Tatra*, 8 *Skoda*), Sweden (7), and the United States.

The petrol railcar, owing to the light weight of the engine and its high speed of rotation, gives the maximum power to weight ratio, and therefore the best acceleration.

The *diesel railcars* are definitely heavier than the petrol railcars and are, therefore, less advantageous as regards acceleration.

The diesel engine, nonetheless, is the one most generally used in modern railcars, for the following reasons :

1. High-speed diesel engines are available up to at least 400 H.P.;

2. The high-speed diesel engine has not yet reached the same degree of perfection as the petrol engine, but has benefited by the experience obtained with the latter, besides being a development of the stationary diesel which has been in use for many years and has cost next to nothing in upkeep;

3. The diesel engine is economical; its thermal efficiency is much higher than that of the petrol engine. The consumption is practically proportional to the power developed by the engine, unlike in the case of petrol engines. Then too, gas oil is cheaper than petrol in most countries.

4. Finally gas oil is less inflammable than petrol.

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II. — **Steam railcars.**

Before there was any question of diesel railcars, many countries built steam-railcars, most of which are still in service. Steam railcars have in fact many advantages :

1. Great starting acceleration, provided, of course, the power of the engine and the evaporative capacity of the boiler are adequate; with steam, as in locomotives, the maximum starting effort possible with the available adhesion can be developed.

2. Easy driving, the driver only having to use the reversing lever and regulator handle.

3. Maintenance costs reduced to the minimum owing to the sturdy design of the engine and the absence of any delicate parts as in mechanical transmissions, such as gear box, clutch and reverse gear.

To counterbalance these undisputed advantages the thermodynamic efficiency of the steam cars is barely *one third* of that of the diesel cars; they therefore require three times the weight of liquid fuel (although of a cheaper grade). Then too they have to carry a supply of carefully treated water 6 to 8 times the weight of the fuel carried. The result is that for the same radius of action, the supplies for the steam railcar are 20 to 40 times heavier, and more bulky, than in the case of the diesel railcars (for example, the amount of fuel and water required for a run of 100 km. [62 miles] is 3 to 4 tons in the case of a steam car compared with 100 kgr. [220 lb.] for a diesel car).

Railways are now developing steam railcars with condensing engines. The *Doble* boiler, now under development at the Sentinel, the Henschel, and the Besler Works, is a monotubular high-pressure boiler supplying superheated steam at 400° C. (752° F.) at between 70 and 80 kgr./cm² (995 to 1 140 lb. per sq. inch) pressure. In this boiler the water is first of all heated, then evaporated, and finally superheated in the same coil. The difficulty with this boiler is to prevent the coil choking up with coke deposits due to the cracking of small quantities of oil the water carries with it along its circuit.

The *Doble* railcars, the first of which has been in service for a year between Hamburg and Lubeck, are automatic, need only small quantities of fuel, and are suitable for single-man operation.

The Doble railcars are extremely interesting but apparently not yet quite perfected. Experience alone will show if the cost of maintenance of the many delicate parts fitted is not as

great as that of the extra man needed for the non-automatic steam railcars.

The fittings in the Doble cars are indeed very complicated, as well as regards the automatic *feed in water and oil* (thermostat and pressure elements actuating electrical contactors which open and close the electro-valve circuit controlling the feed pump and the air nozzle of the burner) as for the *safe working* of the high-pressure boiler and finally the *remote control* and *reversibility* of the railcars.

* * *

III. — Petrol railcars.

Petrol engines are particularly suited for railcar use. Owing to their low weight per horse-power (a 220-H.P. Hispano engine only weighs 320 kgr. [701 lb.] or 1.4 kgr. (3.09 lb.) per horse-power), and their high speed (2 500 to 3 000 revolutions instead of 1 000 to 1 500), they allow of maximum power being obtained with minimum weight, and therefore maximum acceleration.

As a matter of fact, the record acceleration of a vehicle on rails is that of the 32-seater *Micheline* which attained a speed of 80 km. (49.7 miles) an hour in 42 seconds. This Micheline has 25 H.P. per ton and weighs only 143 kgr. (315 lb.) per seat.

It must not be imagined that railcar builders have been able to find the exact engines wanted, even among the wide range of petrol engines available. Lorry engines as a rule do not exceed 120 H.P. and aircraft engines are too highly developed to be reasonably cheap in first cost. The builders have therefore used lorry engines for powers up to 120, and for higher powers, that is to say in practice up to 220, racing car engines, such as Hispano and Bugatti, grouped, if need be, in twos or fours.

The railways take every precaution to avoid all danger of fire and in this case again have profited by the valuable practice obtained in aviation. The precautions taken on the French petrol railcars, especially on the Michelines, are exactly the same as on commercial aircraft.

Apart from the fire question, petrol railcars use a higher-priced fuel and consume much more of it, especially at low loads, for the same useful power. The corresponding cost is more or less made good by the savings in maintenance.

Recent petrol railcars can be divided into two types :

1. Railcars running on pneumatic tyres;
2. Railcars running on metal tyres.

1. *Railcars on pneumatic tyres.*

The AUSTRO-DAIMLER and the MICHELINES are examples of this type.

In the case of the Austro-Daimler, the pneumatic tyre runs within a metal drum and is thereby protected to such an extent that it has only to be renewed after a very great mileage.

The tyres on the Michelines run directly on the rail and the adhesion and braking is improved thereby.

Generally speaking experience has shown that the metal frame is very effectively protected by the pneumatic tyre. Some of the 24-seater Michelines, put into service in December 1934, have each run over 210 000 km. (130 500 miles); the frame work, though extremely light, as the vehicle only weighs 4.7 t. (4.6 Engl. tons), shows no signs of fatigue.

2. *Railcars on metal tyres.*

The *Fiat, Breda, Bugatti,* and *Brill* railcars with horizontal engines are of this type.

Fiat and Breda. — One interesting feature in the Fiat car is that with single suspension it has been possible to build a vehicle which runs very

steadily and is most comfortable even at high speeds. The *Fiat* and *Breda* cars have the engines on the bogies. The engines are very small and as they do not take up any body room the passengers can see out in all directions.

Bugatti railcars. — These cars are carried on eight-wheeled bogies of special design fitted with elastic wheel centres. The engines are grouped in an engine room at the centre of the car, and the passengers in these vehicles have not the impression of being in a railway vehicle.

Brill railcars with horizontal engines. — The horizontal petrol engine is now being widely used on railcars and buses in the United States and leaves the whole of the interior space available for passenger use.

Special precautions have to be taken to keep the combustion gases out of the passenger compartments.

* * *

IV. — Railcar diesel engines.

Diesel engines for railcars should have the following qualities :

Power.

Theoretically the power required to obtain the required performance with a railcar of given form and known weight can be calculated. Practice has shown, however, that a large excess of power over that obtained by calculation has to be provided, so as not to wear out the engines too soon, and in addition to get good acceleration.

Most railways to-day consider that railcars for secondary lines with many stops, as for main-line high-speed railcars, should have a power/weight (in tons) ratio of at least 10.

The greater power has been obtained by increasing the number of cylinders, which sometimes involves special cylinder layouts (V or square engines), or by supercharging (Maybach, M.A.N., Mercedes-Benz).

The increase in engine speed, most European engines of from 150 to 400 H.P. now running at up to 1 500 r.p.m., apart from the greater power that can be developed, reduces the weight of the transmission, whether mechanical, electric, or hydraulic, considerably.

Endurance.

The diesel engine ought to stand up to its work and give no trouble in service.

Many railways prefer to use railcars with two engines, and have insisted upon each set of transmission gear being independent of the other so that if one engine fails the passengers can still be worked to destination.

Much of the trouble experienced with diesel engines is due to irregular combustion, either at starting through failure to fire at the first revolution, or during the run through changes in the engine load resulting in incomplete combustion.

In this respect the importance of the injection pump, too frequently manufactured independently of the diesel engine itself, is fundamental. Also the type of injection (direct injection or with precombustion chamber, or with auxiliary air chamber). Direct injection gives the highest pressures and is generally preferred to-day. As for air injection, it has gone out almost entirely.

Light weight.

The diesel engine should be as light as possible. Although it might not be expected, a diesel engine, all things being equal, is lightened by increasing the number of cylinders.

The lightest diesel at the present time is the 410-H.P. Maybach V engine, which

weighs 2 100 kgr. (4 630 lb.), i.e. 4.7 kgr. (10.36 lb.) per H.P.

Some further reductions in weight may possibly be obtained in the future by means of two-stroke diesels with their great advantage of one driving stroke out of two instead of out of four. For equal power, the weight of a 2-stroke engine, including the scavenging pumps, is generally taken as 70 % of that of a 4-stroke.

Minimum room taken up.

Lengthwise, a diesel engine should take up as little room as possible in the railcar, so as to leave as much space as possible for dealing with the passengers and luggage.

Horizontal diesel engines, such as the C. K. D. 150-H.P., Skoda 120-H.P., and Deutsche Werke 180-H.P., have been introduced recently and as they can be located under the body the inside of the car is left completely free.

Economy in fuel oil and lubricating oil.

The engine should have the lowest possible fuel consumption. In practice, the consumption of different engines only varies slightly (for example, between 180 and 210 grammes [0.397 lb. and 0.463 lb.] per H.P./hour at the rated power of the engine).

The consumption of lubricating oil varies much more and, according to the engine, has either very little or a very appreciable effect on the cost of running.

Some diesel engines, when nearly due for general repairs, use nearly as much lubricating oil as fuel oil.

* * *

V. — Railcar transmissions.

When mechanical transmission is fitted the engine speed in each gear is definitely linked up with that of the railcar, so that at each change of gear the speed of the engine is suddenly changed and thereby its useful power.

The ideal would be to have a continuously variable gear as with the electric transmission, and more recently the hydraulic.

Electric transmission is particularly simple in use, and protects the engine against any possible mishandling by the driver. Its heavy weight and high first cost are against it.

Hydraulic transmission automatically gives the desired torque as a function of the engine speed. Its theoretical efficiency, its ease of control, and its low weight all make it most attractive. In spite of the manufacturers' efforts, it has only proved itself for horse-powers not exceeding 100.

The good and bad features of all these transmissions are more clearly known to-day as the result of the experience of both builders and railways during the last two years.

Mechanical transmission.

A railcar with mechanical drive usually has the same details as an automobile.

The earliest railcars were fitted with lorry gear boxes with sliding gears, which were soon found to be inadequate for the work required of them. Constant-mesh (Maybach, Renault, Ganz, Fiat, etc.) boxes, and epicyclic (Cotal, Wilson) gear boxes were fitted in their place.

The efficiency of modern mechanical transmissions is remarkable, and regularly reaches 92 % as between the engine and the wheels. One railway has even obtained an efficiency of 96 % on direct drive. The maintenance costs of a good mechanical transmission are insignificant.

Although we might have thought otherwise, mechanical transmissions really do not seem to fatigue the engine, even with much gear changing, as when working local services on secondary

lines. One railway proved this by comparing two railcars of the same size and with the same engine, one with mechanical and the other with electric transmission.

The use of mechanical transmissions is therefore increasing, and in Europe they are currently employed up to 250 and even 280 H.-P.

Electric transmission.

The manufacturers have put on the market extremely clever electric transmissions which have been described on many occasions in the press. Each design has some particularly interesting feature not found in the others, so that the railways have ample choice of an entirely satisfactory transmission, free from the apparent complications of mechanical transmissions.

Unfortunately electric transmission manufacturers have too often forgotten to pay sufficient attention to the conditions imposed by the high-speed diesel, and in particular the following :

1. The diesel engine should not be called upon to develop its full torque at low speed.

2. There should be no danger of the electric transmission dividing the power between the n-1 cylinders when the nth fails.

3. The electric transmission ought not to overload the engine through variations in the atmosphere temperature or in that of the electrical circuit.

4. The electric transmission should not suddenly throw the load on to the diesel.

The result has been the very serious trouble experienced in several countries using electric transmission. To prevent any recurrence, the makers have had to make the transmission more complicated, and therefore heavier and more expensive.

Until the hydraulic drive has proved its reliability, the railways are not hesitating to use electric transmissions, which are giving excellent results when used with the sturdy and relatively slow running diesel engines generally fitted in America, and are already giving satisfaction at the present time with fast running European diesel engines.

The highest efficiency of the best electric transmission is about 83 %.

Hydraulic transmission.

So far, hydraulic transmission has been used on low-powered railcars only (*Austro-Daimler, Leyland, Trilok...*) ; it has just been fitted to three 1 200-H.P. triple railcars on the Deutsche Reichsbahn.

The classic hydraulic transmission consists of two hydraulic circuits, one corresponding to the torque converter, the other to the coupler. The coupler forms a clutch lock as between the engine and the car. Under these conditions, it is difficult for the driver who relies on the speed indicator to know if anything has gone wrong with the diesel engine, as the speed of the engine and that of the vehicle are tied together. In the latest designs, no coupler is used and instead, as in mechanical transmission, several torque converters, each being used for a range of speeds corresponding to its maximum efficiency. The efficiency of the hydraulic transmission would then be about 85 %.

* * *

VI. — **Railcar bogies.**

The problem of the vertical stability is the same with railcars as with carriages. Nearly all builders have provided satisfactory vehicles by applying the principles established by the long experience of the railways and by the more recent experience with motor cars.

The transverse stability of railcars is a more complicated problem, because of the following essential differences bet-

ween railcars and the carriages of a train :

1. The vehicles of a train are mechanically connected and this damps out the movements of the vehicles relatively to the track; there are no such connections in the case of the railcar which usually runs as a single vehicle.

2. In a train, only the locomotive has driving wheels, and the tractive effort of the locomotive moreover exercices a steadying effect, at least on the first few vehicles of the train. In the case of the railcar certain pairs of wheels propel the vehicle which, if only one power bogie is fitted, is either pushed or pulled by this bogie according to the direction of running.

3. Some railcar bogies may be used to carry bulky and heavy equipment, such as engines, gear boxes, etc.

The builders have adopted two forms of construction which have long been used by the railways :

— the first with no bogie bolster with the centre carried directly on the bogie frame;

— the second, with a bolster carried from the bogie frame by inclined or parallel swing links which allow the body to move sideways relatively to the bogie and, therefore, to the axles.

This latter arrangement has been used in all coaches having to run at high speeds, because it provides the required degree of comfort. The superiority of bogies with bolsters is not unanimously admitted, and some builders prefer the type of bogie without a bolster.

Railcars, however, are light vehicles running alone, and undergo severer thrusts through the guiding action of the track and when running over points and crossings than heavy coaches in trains.

The obviate these thrusts most builders use indiarubber extensively. Other makers control the relative movement of the body and bogie by using friction- or hydraulic shock absorbers.

Shock absorbers have certain disadvantages either due to the nature of the shock absorber itself, or to defective adjustment when repaired. If the shock absorber checks the side movement of the bogie it also acts as a brake preventing its return to its normal position when the force causing the displacement no longer acts. For this reason many railways prefer not to use shock absorbers, and have endeavoured to meet the difficulty by using tyres of special profile (coned 1 in 40, or cylindrical) in high-tenslie steel, to prevent the tyres wearing too quickly.

Some railways fit the engine on one of the bogies, others in the vehicle. The former method facilitates the drive from the engine to the axles and makes it easier to replace a damaged engine by another.

The advantages of the second method are that the engine is protected from the shocks and vibration the bogie is subjected to, the engine is sheltered from dust, and can be attended to whilst running. The control can be by means of rodding at the minimum of cost.

This method was criticised sometimes on the ground that the noise and vibration of the engine may inconvenience the passengers. Experience has shown that such vibrations can be absorbed by carrying the engine on rubber blocks, by fitting a double bonnet, and by separating the engine from the passengers by one or a number of partitions.

American railways prefer to locate the engine in the body, whereas in Europe the more usual arrangement is to carry the engine on the bogie.

* * *

VII. — **Railcar brakes.**

The following types of brakes are used in modern railcars :

a) drum brakes developed from automobile practice;

b) block brakes as used on railway vehicles;

c) brakes with shoes acting on the outside of drums as in the German high-speed railcars;

d) electromagnetic brakes.

With the drum brake the friction between the brake lining and the drum is constant at all vehicle speeds, so that the fullest use can be made of the brake at high speeds without any fear of the wheels picking up as the speed falls.

With the ordinary block brake, the friction increases considerably as the speed falls so that the brake must be applied moderately at high speeds if the wheels are not to skid at low.

The drum brake therefore appears to be the best for fast railcars. The rapid wear of the linings and the difficulty of finding room for the drums have forced the builders to use block brakes with the block pressure automatically regulated in terms of the speed (*Jourdain-Monneret, Westinghouse,* New York Brake Company *D. C. E.,* etc.).

In Italy, brake linings have been made giving 80 000 km. (50 000 miles) with drum-type brakes, a much better result than anything obtained elsewhere.

Some railways (United States, France) are trying the eddy-current brakes (chiefly for reducing speed on mountain lines) which have the valuable feature that the brake power is proportional to the speed.

The electromagnetic brake is extensively used in several countries. On several railways it is now used as an emergency brake only, as in practice, it is found to have two serious defects which have limited its use :

1. the electromagnetic brake leaves blue marks on the rails through local heating, and these, because of the change in the molecular structure of the metal, make the rails slightly brittle and liable to crack;

2. the electromagnetic brake sets up induced currents in the rails, which can act on the track relays and upset the signalling when track-circuit operated, especially if direct current is used.

* * *

VIII. — **Railcar underframe and body.**

Most railways have built their railcars on the lines of their ordinary stock, but more or less lightened. This lightening is quite legitimate as a railcar generally runs as a separate unit, i.e. is not formed in a train, so that if it runs into anything such as an obstacle or a lorry at a level crossing, it is not telescoped by the vehicles behind it. The lighter the railcar, the less the momentum to be absorbed in a collision and the less the damage to be feared. For these reasons, railcars should be built as lightly as possible of high-tensile materials suitably assembled.

Several American railways have made practical applications of this theory, and have built railcars of 8 % nickel, 18 % chromium stainless steel with an elastic limit of 85 kgr./mm² (54 Engl. tons per sq. inch) and a breaking strength of 105 kgr./mm² (66.7 Engl. tons per sq. inch). Messrs. Budd have developed welding methods of great ingenuity in connection with this steel which is rustless so that the thickness and therefore the strength does not fall off with time.

This form of construction does not, however, show the weight reduction expected. The *Zephyr* rake, 59 m. (193 ft. 7 in.) long, weighs 88.5 t. (87.2 Engl. tons) against the 99 t. (97.4 Engl. tons) of the 62-m. (203 ft. 5 in.) Dutch rakes.

The connection of the body to the bogie is also a serious difficulty with this type of construction. Heavy steel box girder castings have to be used and are difficult to connect to the thin sheets of stainless steel.

Without going to this length, however, some European and American railways have used special 50-75 kgr./mm² (31.75 to 47.62 Engl. tons per sq. inch) steels. They found, in practice, that when the steels are subjected to higher stresses than those usual in rolling stock the vibrations of the plates increased and the comfort was reduced, especially at high speeds.

Corten steel, however, appears to be highly thought of in the United States of America.

Some European railways have tried to make better use of steel. For example, the Dutch railcars are built of round or square 0.25 % copper-bearing steel tubes. These tubes are either hot drawn or from bent and welded plates.

The practice on most railways is to use ordinary steel and pay particular attention to the construction. The plates are thinner than in ordinary stock, all sides of the body take their share of the load and are welded together in accordance with the latest practice. In high-speed streamlined stock, the fixed lights reduce the weight a little, stiffen the body, and also by keeping out water or damp from the body sides, prevent rusting.

A number of railways are using aluminium and duralumin, principally in parts not called upon to take any load. The Union Pacific, the New York, New Haven and Hartford (*Comet* train), and the French Midi have built body framing entirely of aluminium, and the weight is very low, the eight-wheeled Charentaise railcars, for example, with 50 to 60 seats, only weighing 10 tons empty.

* * *

IX. — Comfort in railcars.

Most railways intend to operate railcar services, on secondary lines as well as on main lines, at higher speeds than those of the ordinary trains. The question is to give the passengers, travelling at high speeds in very light rolling stock, comfort at least equal to that provided in steam trains. This problem is particularly complicated and is only being tackled now.

Generally speaking the railcar is more sensitive to permanent way defects than the ordinary rolling stock. Secondary lines are usually less well maintained than the main lines, so that four-wheeled railcars are not suited for high speeds on such lines. The four-wheeled car does not take curves at high speeds so well as a four-wheeled vehicle in a train, as the latter is to some extent guided by the vehicles on each side of it.

These reasons have led most of the railways to use bogie cars on secondary lines instead of four-wheelers, whenever a faster service has to be worked.

The comfort of bogie railcars at high speeds depends upon :

a) the way they ride. No resonance between the periods of the different groups of springs. No hunting;

b) the comfort inside, the seats absorbing the small vibrations transmitted by the body;

c) sound insulation of the car;

d) air conditioning.

Rubber, which gives such excellent results in absorbing small vibrations, when it is free to deform, has not given the perfect results expected when used in bogies as silent-blocks or in steel-tyred elastic wheel centres. The best results on bogies are given by a combination of laminated and coiled springs.

Rubber comes into its own, however, on pneumatic-tyred vehicles (*Michelines*) which make no noise in running even over rail joints.

Sound insulation is being given attention by most railways. A great improvement has been effected by making

the railcar body as airtight as possible, and closing up the smallest openings.

Full air conditioning (heating in winter, cooling in summer) has been provided only in the modern American railcars and a few European luxury coaches. The equipment for air cooling is costly and heavy and uses much power.

* * *

X. — High-capacity railcars. Triplet sets.

Triplet sets have been or are being built in seven countries : Germany, Belgium, Denmark, United States, France, Holland, and Italy. They are fitted out as first-class cars (Italy—France) or for all classes (other countries). The number of seats varies widely, depending upon the interior arrangement adopted, from 92 in Italy to 229 in Belgium for rakes of about the same length, i.e. 59 m. (193 ft. 7 in.).

All the triplet sets are fitted with diesel engines of a total horse-power of 800 to 1 200 according to the country. They are carried on four bogies (two articulated) in all cases, except in France where six bogies are fitted. The French builders prefer six bogies for the following reasons :

1. The six-bogie set can be made longer than those on four bogies. The French rake is, in fact, the longest, being 66.30 m. (217 ft. 6 in.) long as compared with 63.60 m. (208 ft. 8 in.) in Denmark, 62.10 m. (203 ft. 8 in.) in Holland, 60.15 m. (19 ft. 4 in.) in Germany, and 59 m. (193 ft. 7 in.) in Belgium.

2. The articulated bogie is very heavy and does not save much weight.

3. When articulated bogies are used the work of removing a bogie or intermediate body is difficult and requires special plant, as American practice proves.

4. The articulated bogie with double centre is always difficult to maintain. The double pin bogie has been tested in Holland, but is not likely to be used in the future.

5. The braking is easier in the case of rakes with ordinary bogies. For the same deceleration, the brake blocks of rakes with ordinary bogies have to do less work, as more wheels are braked.

The future may therefore well lie with triplets with six bogies which can run at all speeds without appreciable reaction between the vehicles composing it.

* * *

XI. — Comparative tests of railcars.

Several railways have carried out systematic running tests with their railcars, to ascertain the principal constants, namely the rolling resistance, the aerodynamical (air) resistance, the efficiency of the transmission, the efficiency of the gear box, the gradient climbing capability, and the acceleration aptitude.

These interesting tests confirm the value of the theoretical formula :

$$W = \frac{V}{75} (F_0 P + KS V^2)$$

in which W = horse power at the wheel tread;
P = weight in tonnes;
F_0 = Rolling resistance coefficient which in practice is as low as 1.7, and rises to 2.6 in certain heavy railcars with electric transmission;
KS = Air resistance coefficient which in practice is hardly less than 0.40.

Using this formula, and *knowing the approximate efficiency of the transmis-*

sion and the power W in terms of the speed, the acceleration can be calculated at any instant.

These tests have shown the practical value of drawing the curve of « *gradient climbing ability* » to characterise each railcar, as it gives at the same time :

1. the acceleration in terms of the speed;

2. the maximum speed that can be reached running up a given gradient.

It is to be hoped that all countries will subject their more recent railcars to systematic running tests following the method perfected by Messrs. Ferrand and Rousselet. This will give for each railcar the constants F_0 and KS, and the curve of gradient climbing ability.

Practical and simple tests taking only a few days per railcar would enable particularly valuable comparisons to be made, provided the same method were used everywhere.

* * *

XII. — Cost price of railcars.

Most railways were led to build railcars to profit from the very low cost per mile such vehicles were expected to show.

Whereas at the time of the orders, the railways could only estimate what the probable costs would be after running some 300 000 km. (186 400 miles) or more, to-day they have the satisfaction of finding that the cost per mile after running such a distance is entirely reasonable.

The cost of a railcar-mile is usually taken to-day as less than half that of a steam train, according to the service operated.

Railcars do in fact show large savings:

1. On the cost of enginemen and guards' wages which can be halved by doing away with the fireman and one of the train men;

2. on the fuel costs, as the cost of fuel oil is less than half that of coal;

3. on the cost of maintaining the engine;

4. finally on the amortization charges which, although calculated over fewer years, can be spread over a very great mileage as it is possible to pool the railcar and work it the whole of the day.

The great thing was to learn if the cost of engine maintenance was to increase rapidly and become prohibitive. The experience with railcars in Belgium, Denmark, Czechoslovakia, Germany, Austria, and Hungary is reassuring in this respect, and provided periodical repairs are carried out systematically [for example decarbonising every 30 000 to 40 000 km. (18 640 to 25 000 miles) and general repairs including stripping down every 60 000 to 80 000 km. (37 280 to 50 000 miles], the engines will give at least 300 000 km. (186 400 miles) without undue expenditure.

Proposed summaries.

I. In the opinion of most railways, rail motor cars are just what is wanted to satisfy the public demand for some faster services, and the low cost of the railcar-mile will make it possible to effect appreciable operating savings.

Consequently, these railways have ordered large numbers of railcars, necessarily of varying types, as the prototypes are still in the experimental stage.

Over 750 railcars or rail motor trains are at present under construction or on order, to 85 different designs.

Railcars with internal combustion engines (especially diesel-engined are generally preferred at the present time.

II. In spite of their theoretical advantages confirmed by long experience, especially in Great Britain, the coal-fired steam railcars are only ordered now in small numbers.

The steam railcar of the Doble system, entirely automatic and condensing, the first example of which has been running in Germany since last year, appears to have a great future when the delicate technical features of the design have been perfected.

III. In Italy, France, Czechoslovakia and Sweden, petrol engines are favoured. When the same fire precautions are taken as on aircraft, the additional fire risk inherent in petrol should be next to nothing.

IV. All powerful railcars and all multiple-unit sets (with the only exception of the Bugatti, which has 4 petrol engines, and the Danish rail motor rake, with 250-H.P. diesel engines), are now equipped with diesel engines of 400 H.P. and over, which are now so improved that they may be relied upon to work the services very well.

The rotational speed of the diesel engines seems to lie between 1 400 and 1 500 r.p.m. in Europe, whatever the power (150 to 600 H.P.), and between 1 000 and 1 200 r.p.m. in the United States.

A great effort is now being made to perfect the two-stroke diesel engine in the hope of saving an appreciable amount of weight relatively to the four-stroke engine.

V. Mechanical transmission has gained ground over electric transmission, during the last two years, especially in Europe. It is commonly employed now up to 250 and 280 H.P. and, contrarily to what might be feared, it does not seem to fatigue the diesel engine. It has the advantages of efficiency and lightweight.

— Electric transmission is still being preferred in the United States for all applications, and in Europe for high-powers. However, it imposes a heavy strain on the diesel engine if not perfectly adapted to it.

— Hydraulic transmission has not yet proved its value above 100 H.P. approximately, but much may be hoped for from the Reichsbahn's three 1 200-H.P. triplet rakes which are to be fitted with hydraulic transmission.

VI. Railcar bogies are generally lighter than those used on ordinary rolling stock. The are fitted with double suspension in some cases, and single in others. To prevent hunting at high speeds many railways, especially in America, are fitting shock absorbers so far with satisfactory results.

VII. Drum brakes are satisfactory on light railcars. On heavy railcars, the block brake with or without automatic regulation of the pressure in terms of the speed, is more generally used.

The electromagnetic brake remains an interesting proposition, at least as a standby brake, in spite of a few drawbacks found in service.

VIII. The use of special metals (aluminium, high-tensile steels such as « Stainless », special steels such as « Corten », does not appear so far to result in very large weight savings in the construction of bogie railcars, as compared with ordinary steel. The strength of the body to a large extent depends on the metal used for its framing. Most of the Administrations therefore still prefer steel.

IX. Bogie railcars are used even on secondary lines for comfort and steadiness at high speeds in place of four-wheeled railcars which only survive in the case of very small units.

As regards the bogies themselves, experience has shown that the combination of laminated and coiled springs gives

greater comfort than the general use of indiarubber. Up to the present time, any additional comfort due to the use of elastic wheels is not in proportion to the additional maintenance cost involved.

X. Germany, Belgium, Denmark, the United States, France, Holland and Italy are operating or building high-capacity triple railcars. The Danish, American, French and Dutch rakes are already in service.

It appears that the use of ordinary bogies instead of articulated bogies will allow of lengthening the rakes and effecting appreciable savings in maintenance costs.

XI. In view of the valuable conclusions come to in several countries through using the Ferrand-Rousselet method of calculating the characteristic constants of railcars, this method should be used by the largest possible number of railways, to enable them to compare their modern railcars.

XII. It is considered at the present time that the cost of the railcar-mile is at most half that of the steam train-mile. The railcar runs faster than the steam train, but carries fewer passengers.

[621. 45]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

Enlarged Meeting of the Permanent Commission
(4-6 July 1935).

Summary of sectional proceedings.

QUESTION I :

Rail motor cars from the point of view their construction.

A) Types of engines. — Forms of transmissions. — Running gear. — Brakes.
B) Underframe and body. — Heating and ventilation. — Auxiliary apparatus. — Fire precautions.

Preliminary documents.

Part A :

Report *(Countries of the European Continent)*, by Messrs. L. DUMAS and J. LÉVY. (See *Bulletin*, October 1934, p. 1013).

Report *(Other Countries)*, by E. WANAMAKER. (See *Bulletin*, January 1935, p. 7).

Part B :

Report *(Countries of the European Continent)*, by Messrs. L. DUMAS and J. LÉVY. (See *Bulletin*, June 1935, p. 616).

Report *(Other Countries)*, by E. WANAMAKER. (See *Bulletin*, June 1935, p. 657).

Parts A and B :

Complete and revised report *(Countries of the European Continent)*, by L. DUMAS and J. LÉVY. (See *Bulletin*, August 1935, p. 887).

Special report, by L. DUMAS. (See *Bulletin*, August 1935, p. 1075).

Meeting held on the 4th July 1935 (Afternoon).

M. LE BESNERAIS, *Directeur de l'Exploitation, French Nord Railway, in the Chair.*

THE PRESIDENT opens the Meeting at 2.30, and welcomes the Delegates.

He then proceeds with the installation of the Bureau. On behalf of the Permanent Commission he proposes, as Vice-Presidents, Messrs :

DORPMÜLLER, General Manager of the Deutsche Reichsbahn (German State Railway Company), and

VELANI, General Manager of the Italian State Railways;

as Principal Secretary, Mr. CHANTRELL, Engineer, Belgian National Railways Com-

pany (Assistant Secretary, International Railway Congress Association); and as Secretaries, Messrs. Bulleid, Assistant to Chief Mechanical Engineer, London & North Eastern Railway, and Hennig, Engineer, Belgian National Railways Company.

He trusts the Meeting will approve this proposal, particularly as regards Messrs. Dorpmüller and Velani, whose Administrations obtained, from the point of view of railcar operation, fruitful results which can provide very useful information.

The President recalls that the question which is to be examined is one of prime interest at the present time. The increasing use of railcars has been brought about by the need to increase train frequency without raising the working costs.

In a general way, the various kinds of railcar can be subdivided into two main types : (1) railcars of relatively small capacity providing a service comparable, to some extent, to that given by road motorbuses, and (2) large-capacity railcars.

With all designs, an essential condition is that their development results in a reduction in expenditure in respect of the staff, fuel, lubricants, as well as maintenance and amortization.

The President points out that Mr. Dumas has drawn up a special report in which he has summed up the whole question. A copy of this report has been handed to the Delegates. He then requests Mr. Dumas to outline the plan adopted for his special report.

Mr. Dumas emphasizes the fact that, whereas the subject under discussion mainly deals with railcars from the constructional point of view, it should be borne in mind that the operating standpoint is paramount to all other considerations. The special report has been divided into 12 chapters, each of which corresponds to a given operating need.

Mr. Dumas enumerates the various chapters, with the corresponding subject dealt with.

The President defines the procedure he suggests be followed in the discussions : Mr. Dumas will briefly outline each chapter, and Mr. Lévy *(Joint Reporter)* will be requested to supplement it in respect of certain particular points; after the ensuing discussion, the Special Reporter will propose such summaries as will reflect the feeling of the Meeting.

The President states that the Permanent Commission wishes this question to be placed again on the agenda of the next Congress. In order to avoid duplication, the findings should, therefore, specially mention the more important points which should be discussed again at the 1937 Congress.

Mr. Dumas expounds Chapter I of his special report : **General**— in which he gives statistics of the railcars under construction or on order, and shows the actual trend as regards railcar design.

Mr. Velani, Vice-President, *(Italian State Railways)* states that over 100 diesel-engined railcars have just been ordered by his System.

As no Delegate wishes to make any further remark, the following summary is adopted :

« I. In the opinion of most railway administrations, railcars are just what is wanted to satisfy the public demand for faster services, and the lower cost per

mile will allow of appreciable savings in the operating costs being effected.

» Consequently these administrations have placed large orders for railcars; as the experiments with the prototypes are far from completed, the vehicles are necessarily of very varying types.

» Over 750 railcars or rail motor trains are at present under construction or on order, to 85 different designs.

» Railcars with internal-combustion engines (especially diesel-engined) are generally preferred at the present time. »

Mr. DUMAS outlines Chapter II of his report : **Steam railcars.**

Mr. BESSER *(German Government)* supplies some information on the DOBLE railcar, in use between Lubeck and Hamburg, which is giving very satisfactory results. The Company which operates this line intends to also apply the Doble system to a shunting locomotive.

Mr. DUMAS points out that Doble locotractors are in use in England, on the London Midland and Scottish Railway (200-250 H.P. Doble boiler).

Mr. DORPMÜLLER, Vice-President, *(Deutsche Reichsbahn)* notes that railcars are going through a period of quick evolution, involving deep alterations. To facilitate single-man operation and meet the supply question, endeavours are being made at present to evolve a quite new design.

Mr. DUMAS reads the summary suggested for this Chapter; it is approved except for a slight alteration requested by the President; it is worded as follows :

« II. In spite of their theoretical advantages confirmed by long experience, especially in Great Britain, coal-fired steam railcars are only ordered now in small numbers owing to their limited working radius.

» The steam railcar of the Doble system, entirely automatic, and condensing, the first example of which has been running in Germany since last year, appears to have a great future when the delicate technical features of the design have been perfected. »

Mr. DUMAS comments upon Chapter III of his special report : **Petrol railcars.**

Mr. CUTTICA *(Italian State Railways)* gives comparative data in respect of petrol railcars and diesel railcars of equal capacity (56 seats). The difference in weight (due to the engines) is only about 100 kgr. (220 lb.). The speed of the petrol engine is only 2 000 r.p.m., which ensures a long life to the engine; the diesel engine speed is 1 600 r.p.m. The Italian Railways find diesel railcars very satisfactory.

Mr. Cuttica notes that the latter railcars are safer in case of collision. He, however, points out that, in the case of petrol railcars, there would only be unavoidably a fire outbreak if the impact were of such force as to burst the petrol tank. The Italian Railways have not recorded any fire outbreak outside these conditions, not even in the case of backfiring.

The BREDA railcar, built for a maximum speed of 140 km. (87 miles) an hour, effectively ran very steadily at 162 km. (100.7 miles) an hour.

The FIAT railcar is designed for a speed of 130 km. (80.8 miles). At the aforementioned speeds, the braking tests have given complete satisfaction. Both kinds of engine are overhauled after 25 000 km. (15 500 miles). The petrol engine undergoes a heavy repair after

60 000 km. (37 300 miles); however, this limit, it is hoped, will be raised to 100 000 km. (62 000 miles) and, in some cases, to 150 000 km. (93 000 miles).

As regards fuel consumptions, the 240-H.P. FIAT railcars consume 450 gr. per km. (1.60 lb. per mile); the 90-H.P. diesel railcars consume about 210 to 220 gr. per km. (0.745 to 0.780 lb. per mile).

Mr. LÉVY *(Reporter)* draws attention to the relative importance of fuel consumption and maintenance costs; the latter often constitute the main expenditure. On the other hand, comparisons in connection with fuel consumptions are often vitiated by taxes on fuel; conditions much differ in this respect, for instance, in France and in Italy, as no tax of the kind has to be taken into account in the case of the Italian Railways. Mr. Lévy is also of the opinion that a collision does not necessarily give rise to a fire outbreak on a petrol railcar; such a case occurred in France : the fuel tank did not burst and no fire broke out. It is indispensable to protect the fuel tank and to take precautions similar to those resorted to on aircraft. Especially when filling the tanks, are precautions to be taken, and special devices to be used.

As regards distances worked between overhauls, Mr. Lévy states that 50 000 km. (31 000 miles) is already current practice, and that it is expected to reach 75 000 km. (46 500 miles) shortly, in the case of both the petrol engine and the diesel.

Mr. Lévy lays stress on the advantage due to the little room taken up by the petrol engine.

Mr. DREYFUS *(P. O.-Midi Rys., France)* states that on his System diesel railcars are much longer out of service for repairs than petrol railcars.

THE PRESIDENT points out that such comparisons should be made with identical railcars, except as regards the engines, so as to eliminate all accessory causes for the vehicles being laid up.

Mr. LEINER *(Czechoslovak Government)* states that the Czechoslovak Railways have many petrol railcars in service or even under construction, but that they now give preference to the diesel engine whenever the weight of the railcar is above 15 tons.

Mr. DUMAS, at the request of the President, supplies some information concerning petrol railcars in the U. S. A., where, 5 or 6 years ago, a great number of railcars mostly with 300-, 400- and 600-H.P. petrol engines had been built; the present-day tendency, however, definitely favours the diesel railcar, except as regards low powers.

Mr. STROEBE *(Deutsche Reichsbahn)* states that the Reichsbahn at present owns 40 petrol railcars and has gone over to diesel railcars mainly for the sake of safety. The Reichsbahn now owns 150 diesel railcars, their power reaching 400 and even 600 H.P.

Light overhauls occur after 20 000 km. (12 400 miles), which makes it possible to only resort to heavy repairs after 150 000 km. (93 000 miles) have been covered.

Mr. Stroebe also mentions that a 180-H.P. diesel engine with horizontal cylinders has just been built and has successfully undergone bench tests.

— After a short discussion in which the PRESIDENT, Messrs. MICHEL *(French*

Government), Lévy and Cuttica take part, the following summary is adopted :

« III. In Italy, France, Czechoslovakia and Sweden, petrol railcars are favoured, especially light railcars. When the same fire precautions are taken as on aircraft, the fire risk inherent in petrol should be definitely lessened. »

Mr. Dumas then comments upon Chapter IV of his special report : **Railcar diesel engines.**

Mr. Cuttica gives information in respect of spare vehicles for meeting failures on the road : 2 per 100 000 km. (62 000 miles) in the case of railcars; 0.6 per 100 000 km. for steam traction, and 0.9 per 100 000 km. for electric traction.

Mr. Lévy speaks of the quality of the fuel oil to be used in railcars equipped with engines having high speeds of rotation, and he states that for engines running at 1 500 r.p.m., all grades of fuel cannot be used. The degree of purity of fuel oil plays a considerable part in the maintenance and the life of the engine, at least of certain parts of it, such as the injectors. As regards the two-stroke or four-stroke cycle, it is not possible to conclude in favour of one or the other.

Mr. Munck *(Danish State Rys.)* draws a comparison between the 2-stroke and the 4-stroke engine without supercharging : the weight of the 2-stroke engine is only 70 % that of the 4-stroke; the 2-stroke engine is necessarily shorter than the 4-stroke; it takes up less room and it is easier to house it; however, its consumption is slighly higher than that of the 4-stroke engine; finally, its first cost and maintenance costs are lower than those of the 4-stroke engine.

Mr. Dumas, regarding the question of supercharging, raised by the President, is of the opinion that no final conclusions can be formulated at present, supercharging still being in the experimental stage.

Mr. Cuttica also stresses the question of fuel oil filtering.

Mr. Stroebe points out that, on the Reichsbahn, fuel oil is always carefully filtered. As regards the quality of such oil, no definitive specifications have been drawn up so far.

Mr. Hennig *(Belgian National Railways Company)* stresses the absolute necessity of letting fuel oil settle and then filtering it.

Mr. Dumas is of the same opinion. In certain depots on the Nord Railway, centrifugal plant has been installed.

The wording of clause IV of the summary gives rise to an exchange of views between the President and Messrs. Dumas, Michel, van Manen *(Netherlands Railways)*, Nicolet *(French State Railways)*, de Boysson *(Paris-Orléans Ry.)* and Munck.

The outcome is that Mr. Dumas will draw up a new wording for that summary, which will take into account the views of the various Administrations, based on the period elapsing between two overhauls and the desire to save weight, also taking into account the engine speed.

Mr. Dumas now gives an outline of Chapter V, relating to **Railcar transmissions.**

Mr. Cuttica supplies information in connection with the mechanical transmission used on an Italian triplet set with

400-H.P. engines; the results are satisfactory.

Mr. LÉVY points out that a 500-H.P. mechanical transmission is now being designed in France.

Mr. STROEBE gives information about the 600-H.P. hydraulic transmissions, which have just undergone trials on the test bench, with very satisfactory results. He also supplies details in respect of the 150-H.P. hydraulic transmissions now in service, and mentions that others for powers of 250, 300 and 400 H.P. are under construction. He stresses the fact that the hydraulic transmission can also be used in braking the railcar on gradients as well as on the level, and this enables the brake gear to be lightened.

Mr. Stroebe also notes that the weight saving which was expected from the use of the hydraulic transmission has not been appreciable; this is due to the mechanical part needed for going over from torque converter working to coupler working.

As regards the efficiency of the hydraulic transmission, it should be noted that, according to vehicle speed, the efficiency of the torque converter lies between 83 and 90 %, that of the coupler between 95 and 96 %, so that an overall efficiency of 80 to 90 % may be reckoned upon.

Mr. DUMAS reads the proposed summary relating to Chapter V. This summary is adopted with an addition in connection with the use of the free wheel, or the hydraulic fly-wheel in the case of mechanical transmission, and another addition regarding braking facilities to be derived from the use of the hydraulic transmission.

It is worded as follows :

« V. Mechanical transmission has gained ground over electric transmission during the last two years, especially in Europe. It is commonly employed now up to 250 and 280 H.P. and, contrarily to what might be feared, does not seem to fatigue the diesel engine. It has the advantages of efficiency and light weight. The free wheel or a hydraulic flywheel complete it in a happy manner.

» Electric transmission is still preferred in the United States for all applications, and in Europe for high powers. However, it imposes a heavy strain on the diesel engine if not perfectly adapted to it.

» Hydraulic transmission has not yet proved its value above 150 H.P. approximately, but much may be hoped for from the Reichsbahn's three 1 200-H.P. triplet rakes, which are to be fitted with hydraulic transmission.

» The hydraulic transmission has the additional advantage of providing supplementary braking power. »

Mr. DUMAS now comments upon Chapter VI of his special report : **Railcar bogies.**

THE PRESIDENT insists on the fact that as regards this question two essential factors arise : transverse stability, and location of the engine.

Mr. CUTTICA states that the various bogie designs are found in the different Italian railcar types, and that the results are generally good.

Mr. LÉVY gives details about a bogie without bolster, but fitted with shock absorbers. Speeds of 150 km. (93 miles) an hour have been reached without the transverse effort exceeding 1 000 kgr.

(2 200 lb.). Consequently excellent stability at high speeds appears to be possible with shock absorbers.

Mr. Stroebe speaks of the new tyre contour adopted by the Reichsbahn on high-speed vehicles, such as the « Flying Hamburger » (Schnelltriebwagen). The former compound 1 in 10 and 1 in 20 taper is now 1 in 20 and 1 in 40. The results are quite satisfactory.

Mr. Dumas is afraid the tyres will wear more quickly under such conditions.

Mr. Stroebe insists on the fact that this new contour is only experimental and that no final conclusions can be come to.

Mr. de Boysson points out that this problem is not special to railcars.

Mr. Lévy again stresses the question of tyre wear and tyre steel.

Mr. Bals *(Rumanian Railways)* asks whether the inclination of the rails in the track was not altered at the same time.

The President answers in the negative.

Mr. Hennig points out that after one year's service, no tyre wear was found on the fast double-railcar used between Brussels (Midi) and Ghent (St. Pierre). He attributes this to the complete absence of hunting, obtained by the use of appropriate spring gear.

Mr. Lévy asks whether the tests on the Reichsbahn were carried out with tyres of different taper fitted to one and the same vehicle.

Mr. Stroebe answers in the negative. The tests were carried out on different vehicles.

Mr. Dumas reads the proposed summary.

The following wording is adopted :

« VI. Railcar bogies are generally lighter than those used on ordinary rolling stock. They are fitted with double suspension in some cases, and single in others.

» To prevent hunting at high speeds, many railways are fitting shock absorbers, so far with satisfactory results. Others have improved the riding by reducing the conicity of the tyres.

» The engine is usually carried on the bogie. Experience, however, has shown that the passengers can be made practically as comfortable when the engine is located in the body as when it is carried on the bogie. »

— The Meeting is closed at 5.30.

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Meeting held on the 5th July (Morning).

Mr. Le Besnerais in the Chair.

— The Meeting is opened at 9.0 o'clock.

The President calls upon Mr. Dumas who expounds Chapter VII of his special report : **Railcar brakes.**

Mr. Cuttica states that the question of brakes, with devices for automatically regulating the block pressure in terms of the vehicle speed, is being gone into in Italy. So far, however, only bench tests have been carried out.

Mr. Cuttica also states that railcar brake linings last through up to 80 000

km. (50 000 miles) of local or through service; the brake must be carefully set.

Mr. Stroebe states that electromagnetic brakes fitted on all fast railcars (Schnelltriebwagen) are used in case of emergency only, except on heavy gradients. The Reichsbahn avoids as much as possible fitting the electromagnetic brake, owing to the considerable additional weight it entails.

Mr. Hennig mentions that on the Belgian National Railways Company the electromagnetic brake has just been fitted on the double railcar, but as a standby only.

Mr. Lévy stresses the interference with the track circuits, which may result from the use of the electromagnetic brake.

Mr. Nicolet wonders whether any Delegate can supply any information in connection with the devices used to regulate the brake block pressure in terms of the speed.

Mr. Stroebe states that brakes with such devices are still in the experimental stage on the Reichsbahn.

Mr. Cuttica says that this is also the case in Italy.

Mr. Dumas mentions that the brake with automatic regulation, built by Messrs. Jourdain-Monneret and fitted to the high-speed rakes of the Nord Railway Company, gives complete satisfaction.

Mr. Nicolet adds that brakes of such kind are being tried on the Renault railcars of the Paris-Orléans Lines.

The President is of the opinion that this is an interesting question and that it should be one of those to be placed on the Agenda of the 1937 Congress.

Mr. Japiot *(P.-L.-M. Railways)* points out that this question applies to all high-speed vehicles.

Mr. Bals desires some information on the Dunlop-Fouga railcar with steel-tyred carrying wheels, and driving wheels fitted with pneumatic tyres.

Mr. de Boysson replies that this railcar has not been in service long enough for any final conclusion to be come to.

Mr. Dumas reads the proposed summary relating to Chapter VII.

The following wording is adopted :

« VII. Drum brakes are satisfactory on light railcars. On heavy railcars, the block brake, with or without automatic regulation of the pressure in terms of the speed, is more generally used. The electromagnetic brake remains an interesting proposition, at least as a standby brake, in spite of the drawbacks found in service.

Mr. Dumas passes on to Chapter VIII of his special report : **Railcar underframe and body** — and comments upon the general table giving data on the triple railcars, a copy of which has just been handed to the Delegates. He concludes by stating that the weight saving obtained by the use of aluminium or stainless steel, is only some 10 %.

Mr. Cuttica stresses the need of strengthening the body ends in order to minimise the results of accidents.

Mr. Dreyfus states that the « Charentaise » railcars in duralumin have been quite satisfactory so far.

Dr. Dorpmüller gives particulars about accidents which occurred on the Reichsbahn. He is of the opinion that it is

not possible, at present, to decide in favour of light or heavy construction.

Mr. Lévy points out that when it is desired to lighten the railcar, the body should first of all be built lighter. When comparing the weight of various designs, it should also be made clear whether these designs are equivalent as regards strength.

Mr. Lévy supplies information in connection with the use of special steels. On examination, tenders for the construction of a light body (maximum specified weight : 12 tons, and also a given strength) have shown that builders using ordinary steel could not go below 15 tons. Those who proposed special steel for the frame members and light-alloy panelling went down to 14 tons; with nickel-chrome steel, the 12-ton mark was reached.

To sum up, THE PRESIDENT notes that 3 tons can be saved on a body 20 m. (65 ft. 7 in.) long.

Mr. DE BOYSSON points out that the builder is limited by the question of deformation of the parts, which prevents their thickness being reduced too much, the modulus of elasticity of special steels being the same as that of ordinary steels.

Mr. DUMAS and Mr. CHATEL *(Nord Railway, France)* are of the same opinion; the question of the bending movements of the body must be borne in mind.

Mr. STROEBE states that on the Reichsbahn the vehicles are heavier because they have to work with trailers, and not for the sake of safety. The Reichsbahn still favours steel. The steel used is the St. 52 (33 Engl. tons per sq. inch), welding being resorted to on a large scale.

Mr. MICHEL points out that, from the standpoint of lightness, comfort is bound up with the ratio of the spring-borne mass to the unsprung mass, so that if it is desired to lighten the body, the unsprung part must be lightened correlatively.

Mr. DUMAS reads the summary of Chapter VIII, which takes into account the various remarks made. The following text is adopted :

« VIII. The use of special metals (aluminium, high-tensile steels such as « Stainless », and special steels such as « Corten ») has not resulted in such large weight savings as would be expected from the relative specific weights or tensile strengths.

» Most railways still prefer carbon steel; some railways, however, use special steels in new stock, to strengthen the body agains shock, in addition to lightening it to some extent. »

Mr. DUMAS comments upon Chapter IX of his special report: **Comfort in railcars.**

Replying to Mr. DREYFUS, he states that the wheels of Austro-Daimler railcars, with pneumatic tyres inside steel tyres, appreciably improve the comfort.

Mr. LÉVY confirms this statement, but on account of the high cost, this system has not been considered on the French State Railways.

Mr. NICOLET thinks an important factor as regards the comfort in railcars is absence of noise; the Micheline, with its pneumatic tyres, is particularly agreeable in this respect.

THE PRESIDENT notes that comfort includes three factors : vibration, noise and air conditioning.

Mr. DUMAS reads the proposed summary, which gives rise to some objections.

Mr. LÉVY points out that the bogie has not been adopted solely for reasons of comfort, but also for the sake of vehicle capacity. He furthermore stresses the excellent results obtained by the well thought-out use of rubber springing, such as on the British railways.

Mr. GRESLEY *(London & North Eastern Railway)* is not in agreement with the second paragraph of the suggested summary. He asks that it be stated in the summary that the combined effect of steel springs and rubber gives the best results.

Mr. DE BOYSSON points out that air-conditioning is an improvement of the luxury kind.

Mr. DREYFUS also stresses the question of ventilation which should be solved on the branch lines as well.

Mr. DUMAS then reads the summary, modified so as to take into account the remarks made. The following text is approved by the Meeting :

« IX. Bogie railcars are used, even on secondary lines, for comfort and steadiness at high speeds, in place of four-wheeled railcars which only survive in the case of very small units.

» As regards the bogies themselves, experience has shown that the combination of laminated and coiled springs, completed by a reasonable use of indiarubber, gives the greatest comfort. Up to the present time, any additional comfort due to the use of elastic wheels is not in proportion to the additional maintenance cost involved.

» The suppression of noise is at least of equal importance for comfort.

» Ventilation is also a matter of great moment. Some Companies have gone so far as to consider complete air conditioning in order to give the greatest possible comfort. »

Mr. DUMAS comments upon Chapter X of his special report, dealing with : **High-capacity railcars. — Triplet sets.**

THE PRESIDENT stresses the fact that there are two points to be considered : (1) the use of large-capacity rakes; (2) the respective value of the articulated (intermediate) bogie, and of the ordinary bogie.

Mr. MICHEL asks that the tendency to build railcars which can be coupled together, be noted.

THE PRESIDENT also thinks it would be interesting to note the present-day tendency towards the use of trailers, also the coupling up of railcars and the construction of triplet railcars, at least in connection with certain kinds of service.

Mr. LÉVY stresses the interest there is in coupling railcars together, and draws attention to the difficulties arising from the use of the complicated control boards which become necessary.

Mr. STROEBE gives particulars on the driving compartments of the Reichsbahn multiple-unit railcars. A special man is needed for watching and controlling the second power set. The Reichsbahn wondered whether this second man could not be done away with, and came to the conclusion that this would involve too great complications, account being taken

of the many duties already imposed on the actual driver of the railcar.

In connection with the question of articulated (intermediate) bogies, Mr. Stroebe states that the Reichsbahn owns 6-bogie triplets and 4-bogie triplets. The latter have given good results from the technical point of view; however, it should be noted that articulated bogies take up more space than ordinary (separate) bogies, so that the choice between the two systems is finally conditioned by the available railcar capacity.

THE PRESIDENT sums up the discussion as follows: The articulated bogie has given goods results; when it is desired to increase the number of seats by lengthening the rake, the intermediate bogie has the drawback that this lengthening out can only be obtained by shortening the body; in the case of large-capacity rakes, one is thus led to revert to bodies carried on two separate bogies.

Mr. NICOLET, in reply to a question from Mr. CUTTICA, gives information about the control of two coupled-up Micheline railcars, each of which is driven by its own driver; an electrical device enables each driver to ascertain the rotational speed of each engine; the very flexible coupling prevents the possible jerks resulting from wrong moves.

Mr. HUPKES *(Netherlands Railways)* gives the meeting a few particulars in connection with the Dutch triplets, operated by one man who controls the speed of the engines and the cooling water temperature.

Mr. BALS states that the Görlitz type bogies, with which several double railcars of the Rumanian Railways are equipped, are quite satisfactory.

Mr. GRESLEY cannot agree as to the second paragraph of the proposed summary; in his opinion, the six bogies of a triple railcar will entail higher capital cost and maintenance costs than when articulated bogies are used.

Mr. DUMAS replies that the articulated bogie, which in most cases is a driving bogie, will as a rule cost as much as two separate bogies. As regards maintenance, returning the tyres of separate bogies, for instance, will cost more; however, there is an appreciable time saving in favour of the separate bogie when the body has to be lifted off the bogie which has to be replaced, unless special plant for dropping the articulated bogie is provided.

THE PRESIDENT sums up the discussion and Mr. DUMAS reads the summary which is adopted under the form shown hereafter, after a short exchange of opinions between the PRESIDENT, Messrs. MICHEL, NICOLET, BALS and DUMAS.

« X. There is a tendency in all countries to increase the capacity of railcars or a desire to be able to vary the capacity according to traffic requirements. Many companies are consequently now using either multiple-unit sets, or cars coupled together or to trailers.

» In multiple-unit sets, articulated bogies are generally used and give the maximum of comfort and steadiness. The use of ordinary bogies in place of articulated bogies, however, enables the set to be made longer and overcomes the difficulties encountered when taking out articulated bogies for repairs or as the result of some accident or other. »

Mr. DUMAS passes on to Chapter XI of his special report : **Comparative tests of railcars.**

Mr. Cuttica mentions that the Italian State Railways intend to carry out such tests.

The President voices the opinion that this question should be especially dealt with at the next Congress, so that results obtained in the various countries may be compared.

Mr. Dumas reads the proposed summary, which is adopted :

« XI. In view of the valuable conclusions come to in several countries through using the Ferrand-Rousselet method of calculating the characteristic constants of railcars, this method should be used by the largest possible number of railways, to enable them to compare their modern railcars. »

Mr. Dumas expounds Chapter XII of his special report : **Cost price of railcars.**

The President stresses the importance of the cost price question from the triple viewpoint of : operating costs, maintenance costs and amortization. He invites the Delegates to state the results obtained and methods used in connection with the reduction of expenses.

Mr. de Boysson makes some remarks in connection with the cost of the railcar-kilometre, as compared with the steam train-kilometre; he thinks the main factors of a railcar service are maintenance costs and amortization charges.

Mr. Lévy stresses the importance of shortening the period railcars are under repair or in reserve.

Mr. Dreyfus draws attention to the need for new shed accomodation and repair plant for railcars.

Mr. Cuttica states that in Italy the existing installations have been used so far; with the advent of multiple-unit railcars, this will be possible no longer. The average daily distance covered by railcars is 250-300 km. (155-185 miles), including spare vehicles.

Mr. Verkoyen *(Belgian National Rys. Co.)* mentions that during the 4 years they have been in use on the Belgian National Railways Co., the railcars with Maybach diesel engines have been out of service 20 % of the whole time, this proportion being 10 % in the case of Sentinel steam railcars.

Mr. Munck states that in Denmark maintenance work on railcars was carried out at first in the locomotive sheds. The results were bad, and when multiple-unit railcars were bought, new railcar sheds were built, which led to an appreciable reduction in maintenance costs.

Mr. Verkoyen states that similar conditions prevailed in Belgium; at first railcars were maintained and repaired in 4 depots, which led to the same drawbacks as were met with in Denmark; since then, engine overhaul work has been centralized in one workshop, provided with special plant and a staff of specialists trained by instructors lent by the engine builders.

Mr. Lévy insists on the training of the men who repair and drive the railcars. On the French State Railways, carefully selected drivers have been trained at a school, whereat they have to go periodically through additional courses.

The President thinks that the cost price is paramount and that this is another special point which should be referred to the next Congress.

Mr. NICOLET raises the question of the bases which should be adopted in connection with amortization charges. In France, a provisional rule has been adopted, according to which the capital cost of stock used under local service condidions is to be redeemed after 500 000 km. (310 000 miles) have been covered. This figure becomes 750 000 km. (466 000 miles) in the case of stock used in semi-through services, and 1 000 000 km. (620 000 miles) for high-speed services.

Mr. CUTTICA states that similar bases have been adopted in Italy.

Mr. DUMAS reads the proposed summary which is modified so as to take into account the remarks made by Messrs. Nicolet, Michel, Châtel, and Lévy, and is approved with the following wording :

« XII. Experience shows that the essential factors in railcar costs are the maintenance costs and the amortization charges. All Companies are endeavouring to reduce their maintenance costs at the present time, even if it means some increase in fuel costs.

» In connection with the amortization charges, any special fixed equipment which may be necessary has to be taken into account; savings can be effected by adapting railcar working conditions to the stock, and by training and specialisation of the staff.

» In many countries, the cost of the railcar-mile, with many types of railcars, is considered at the present time to be only one half and even one third that of the steam trains previously working the same service.

» This last finding shows the great value of railcars and the desirability of dealing with the question again at the next Congress, with special attention to the three points in connection with which progress might be made in the near future, namely : transmissions and brakes, comparative test methods, detailed investigation into costs and the methods by which they may be reduced. »

— The Meeting is suspended for ten minutes to allow the special reporter to make some slight alterations to the summaries which will be submitted for ratification to the Plenary Meeting.

They are reproduced hereafter. The first paragraph of summary II is altered at the request of Mr. Gresley. The text of summary IV has been revised after the Meeting held on the 4th July, in conformity with the decision taken in the course of that Meeting.

Summaries.

« I. In the opinion of most railways, rail motor cars are just what is wanted to satisfy the public demand for faster services, and the lower cost of the railcar-mile makes it possible to effect operating savings.

» Consequently, these railways have ordered large numbers of railcars, necessarily of varying types, as the prototypes are still in the experimental stage.

» Over 750 railcars or rail motor trains are at present under construction or on order, to 85 different designs.

» Railcars with internal combustion engines (especially diesel-engined) are generally preferred at the present time. »

« II. Steam railcars have given satisfactory results, especially in Great Britain, where a considerable number are in service, but where the use of railcars is not being extended owing to operating conditions.

» The steam railcar of the Doble system, entirely automatic and condensing, the first example of which has been run-

ning in Germany since last year, appears to have a great future when the delicate technical features of the design have been perfected. »

« III. In Italy, France, Czechoslovakia, and Sweden, petrol engines are favoured, especially for light railcars. When the same fire precautions are taken as on aircraft, the fire risk inherent in petrol should be definitely lessened. »

« IV. Minimum costs of maintenance, and especially of the periodic overhauls, are the principal factors deciding the diesel engine selected. The value of minimum weight per horse-power must also be borne in mind.

» Diesel engines of many designs and of 250 to 300 horse-power and even over are now available for railcar purposes.

» The various triplet rakes in existence are fitted with 400-H.P. engines and over, the only exception being the Danish rakes which have four diesel engines, each 250 H.P. These engines are so improved today that they can be relied upon to work the services very well.

» In order to make sure of their diesel engines running reliably, most railways take the greatest precautions in connection with their fuel oil which generally complies with certain given technical specifications, and is filtered and decanted before use.

» A great effort is now being made to perfect the high-speed two-stroke diesel engine in the hope of saving a considerable amount of weight relatively to the four-stroke engine. Supercharging is also under test. »

« V. Mechanical transmission has gained ground over electric transmission during the last two years, especially in Europe. It is commonly employed now up to 250 and 280 H.P. and, contrarily to what might be feared, does not seem to fatigue the diesel engine. It has the advantages of efficiency and light weight. The free wheel or a hydraulic flywheel complete it in a happy manner.

» Electric transmission is still preferred in the United States for all applications, and in Europe for high powers. However, it imposes a heavy strain on the diesel engine if not perfectly adapted to it.

» Hydraulic transmission has not yet proved its value above 150 H.P. approximately, but much may be hoped for from the three 1 200-H.P. triplet rakes of the Reichsbahn, which are to be fitted with hydraulic transmission.

» The hydraulic transmission has the additional advantage of providing supplementary braking power. »

« VI. Railcar bogies are generally lighter than those used on ordinary rolling stock. They are fitted with double suspension in some cases, and single in others.

» To prevent hunting at high speeds, many railways are fitting shock absorbers, so far with satisfactory results. Others have improved the riding by reducing the conicity of the tyres.

» The engine is usually carried on the bogie. Experience, however, has shown that the passengers can be made practically as comfortable when the engine is located in the body as when it is carried on the bogie. »

« VII. Drum brakes are satisfactory on light railcars. On heavy railcars, the block brake, with or without automatic regulation of the pressure in terms of the speed, is more generally used. The electromagnetic brake remains an interesting proposition, at least as a standby brake, in spite of the drawbacks found in service. »

« VIII. The use of special metals (aluminium, high tensile steels, such as « Stainless » and special steels, such as « Corten ») has not resulted in such large weight savings as would be expected from the relative specific weights or tensile strengths.

» Most railways still prefer carbon steel; some railways, however, use special steels in new stock, to strengthen the body against shock, in addition to lightening it to some extent. »

« IX. Bogie railcars are used even on secondary lines for comfort and steadiness at high speeds in place of four-wheeled railcars, which only survive in the case of very small units.

» As regards the bogies themselves, experience has shown that the combination of laminated and coiled springs completed by a reasonable use of indiarubber gives the greatest comfort. Up to the present time, any additional comfort due to the use of elastic wheels is not in proportion to the additional maintenance cost involved.

» The suppression of noise is at least of equal importance for comfort.

» Ventilation is also a matter of great moment. Some Companies have gone so far as to consider complete air conditioning in order to give the greatest possible comfort. »

« X. There is a tendency in all countries to increase the capacity of railcars or a desire to be able to vary the capacity according to traffic requirements. Many Companies are consequently now using either multiple-unit sets, or cars coupled together or to trailers.

» In multiple-unit sets, articulated bogies are generally used and give the maximum of comfort and steadiness. The use of ordinary bogies in place of articulated bogies, however, enables the set to be made longer and overcomes the difficulties encountered when taking out articulated bogies for repairs or as the result of some accident or other. »

« XI. In view of the valuable conclusions come to in several countries through using the Ferrand-Rousselet method of calculating the characteristic constants of railcars, this method should be used by the largest possible number of railways, to enable them to compare their modern railcars. »

« XII. Experience shows that the essential factors in railcar costs are the maintenance costs and the amortization charges. All Companies are endeavouring to reduce their maintenance costs at the present time, even if it means some increase in fuel costs.

» In connection with the amortization charges, any special fixed equipment which may be necessary has to be taken into account; savings can be effected by adapting railcar working conditions to the stock and by the training and specialisation of the staff.

» In many countries, the cost of the railcar-mile with many types of railcars is considered at the present time to be only one half and even one third that of the steam trains previously working the same service.

» This last finding shows the great value of railcars and the desirability of dealing with the question again at the next Congress, with special attention to the three points in connection with which progress might be made in the near future, namely : transmissions and brakes, comparative test methods, detailed investigation into costs and the methods by which they may be reduced. »

* * *

— In conclusion, the PRESIDENT notes the great importance attaching to the railcar problem and expresses the wish that the matter be taken up again at the next Congress, stressing three points in respect of which developments may be expected to materialize in the near future : (1) transmissions and brakes; (2) comparative test methods; (3) detailed investigation into the cost price of railcars and methods by which it can be reduced.

THE PRESIDENT thanks the Delegates, who facilitated his task by the precision of their statements on the many points which have been under discussion. He also thinks they will all agree in thanking Belgium and the Management of the Exhibition for their kind and agreeable hospitality. *(Applause.)*

— The Meeting ended at 12.30.

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The text of the above summaries was ratified, subject to a few alterations, by the Plenary Meeting held on the 6th July, the proceedings of which, together with the final summaries, will be published in the September number of the *Bulletin*. *(Editorial note.)*